Draft

Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Volume I - Impact Analyses
Chapters 1 through 15

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250D

July 1999

ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

BWR	boiling-water reactor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPF	energy partition factor
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NWPA	Nuclear Waste Policy Act, as amended
OCRWM	Office of Civilian Radioactive Waste Management
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
PWR	pressurized-water reactor
UFSAR	Updated Final Safety Analysis Report
USC	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
$10^6 = 1{,}000{,}000$ (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

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COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE)

TITLE: Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

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The EIS is also available on the Internet at the Yucca Mountain Project website at *http://www.ymp.gov* and on the DOE National Environmental Policy Act (NEPA) website at *http://tis.eh.doe.gov/nepa/*.

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ABSTRACT: The Proposed Action addressed in this EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action.

PUBLIC COMMENTS: A 180-day comment period on this Draft EIS begins with the publication of the Environmental Protection Agency Notice of Availability in the *Federal Register*. DOE will consider comments received after the end of the 180-day period to the extent practicable. DOE will hold public meetings to receive comments on the Draft EIS at the times and locations to be announced in local media and a DOE Notice of Availability in the *Federal Register*. Written comments can also be submitted by U.S. mail to Wendy R. Dixon at the above address, or via the Internet at *http://www.ymp.gov*.

FOREWORD

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site. The potential repository would be located in Nye County, Nevada. The EIS also provides information on the potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and amended in 1987, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The Nuclear Waste Policy Act, as amended (the EIS refers to the amended Act as the NWPA), also requires the U.S. Department of Energy (DOE) to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. The hearings would be separate from the public hearings on the Draft EIS required under the National Environmental Policy Act. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will notify the Governor and legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considers the site qualified for application to the U.S. Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the legislature submits a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken After Site Designation

Once a site designation became effective, the Secretary of Energy would submit to the Nuclear Regulatory Commission a License Application, based on a particular facility design, for a construction authorization within 90 days. The NWPA requires the Commission to adopt the Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

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1

Purpose and Need for Agency Action

1. PURPOSE AND NEED FOR AGENCY ACTION

Spent nuclear fuel and high-level radioactive waste are long-lived, highly radioactive materials that result from nuclear activities. For more than 50 years these materials have accumulated and continue to accumulate at sites across the United States. Figure 1-1 shows the 72 commercial nuclear power sites and the 5 U.S. Department of Energy (DOE) sites in 35 states that currently store these radioactive materials. Because of their nature, spent nuclear fuel and high-level radioactive waste must be isolated, confined, and monitored for long periods. The United States has focused a national effort on siting and developing a geologic repository for disposal of these materials and on developing systems for transporting the materials from their present storage locations to a repository.

Congress has determined through the passage of the Nuclear Waste Policy Act, as amended (NWPA) (42 USC 10101 *et seq.*), that:

- The Federal Government has the responsibility to dispose of these materials permanently to protect the public health and safety and the environment.
- The Federal Government needs to take precautions to ensure these materials do not adversely affect the public health and safety and the environment for this or future generations.
- The Yucca Mountain site in southern Nevada should be evaluated as a potential location for a monitored geologic repository.

A geologic repository for spent nuclear fuel and high-level radioactive waste is a system for permanently isolating radioactive materials in a deep subsurface location to ensure minimal risk to the health and safety of the public. This environmental impact statement (EIS) addresses actions that DOE proposes to take to develop a repository at Yucca Mountain, and also considers systems for the transportation of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site.

ENVIRONMENTAL IMPACT STATEMENT

An *environmental impact statement* or *EIS* is a detailed analysis that addresses a major Federal action that may significantly affect the quality of the human and natural environment. An EIS describes the potential beneficial and adverse environmental effects of the proposed action and alternatives. It is a tool to assist in decisionmaking and provides public disclosure of information.

In addition, DOE has ultimate management responsibility for other highly radioactive materials. Examples of such materials include Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The Department might need to dispose of these materials in a monitored geologic repository to protect public health and safety. However, disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require additional legislative action or a determination by the U.S. Nuclear Regulatory Commission to classify them as high-level radioactive waste.

Section 1.1 describes potential actions and decisions concerning the proposed repository. Section 1.2 provides an overview of spent nuclear fuel and high-level radioactive waste. Section 1.3 describes the major steps in the process Congress has established for evaluations and decisions concerning the Yucca Mountain site. Section 1.4 provides an overview of the site, potential transportation systems for moving spent fuel and radioactive waste to the site, and studies of the site. Section 1.5 presents information on the EIS process as it applies to the proposal for a monitored geologic repository at Yucca Mountain.

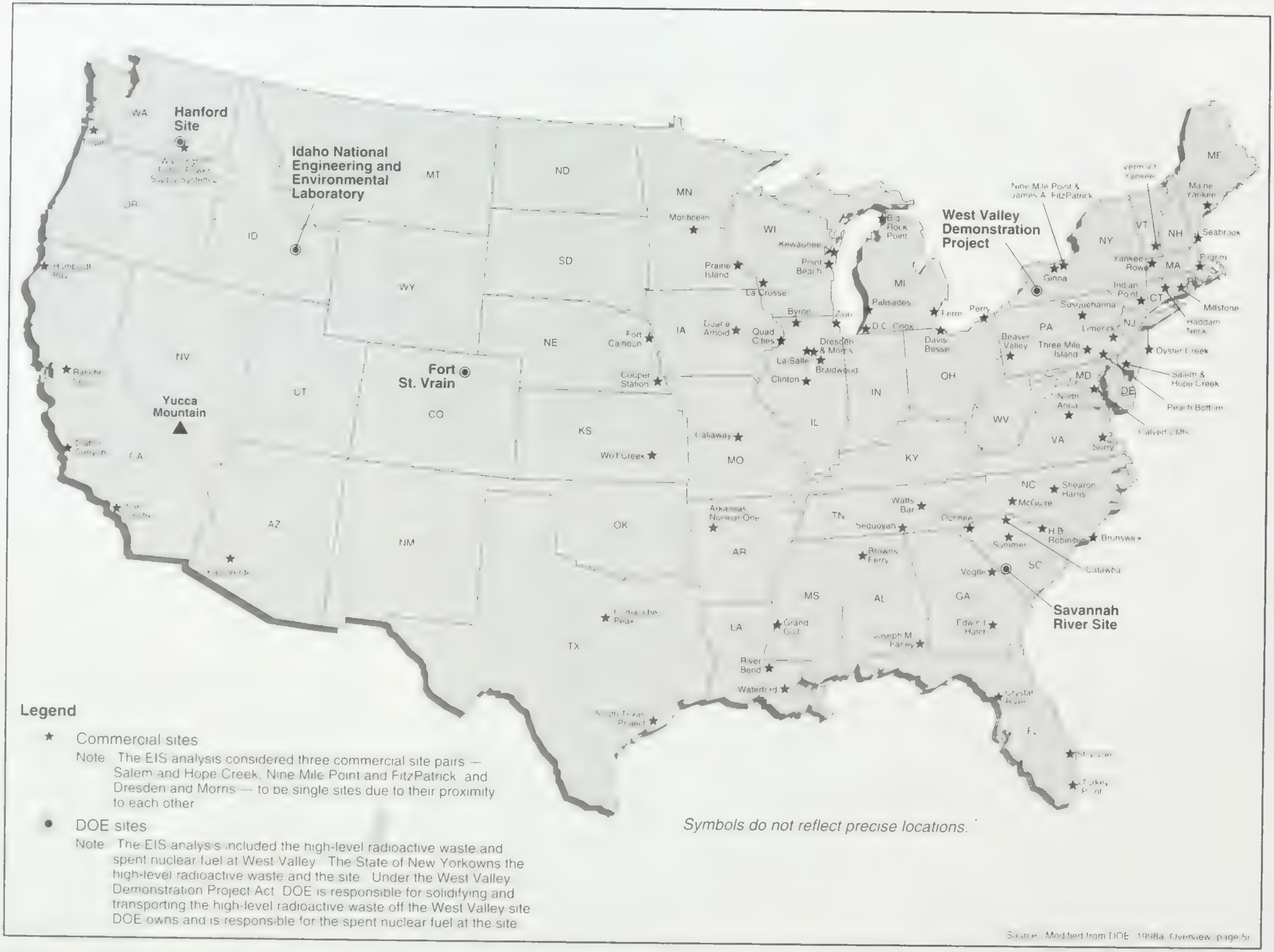


Figure 1-1. Locations of commercial and DOE sites and Yucca Mountain.

1.1 Potential Actions and Decisions Regarding the Proposed Repository

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

PROPOSED REPOSITORY

DOE has used the term *proposed repository* as a term of convenience to indicate the relationship of the Yucca Mountain Repository to the Proposed Action of this EIS. DOE could not pursue the use of Yucca Mountain as a repository until the Secretary of Energy decided whether to recommend approval of the site to the President and a Presidential site designation has become effective. At that time DOE would submit a License Application to the Nuclear Regulatory Commission seeking authorization to construct a repository at Yucca Mountain.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

1.2 Radioactive Materials Considered for Disposal in a Monitored Geologic Repository

Commercial nuclear powerplants, which supply approximately 20 percent of the Nation's electricity, produce spent nuclear fuel. In addition, DOE manages a complex of large government-owned facilities that formerly produced nuclear weapons materials, and in doing so produced spent nuclear fuel and high-level radioactive waste. DOE also operates research reactors that produce spent nuclear fuel and processing facilities that produce high-level radioactive waste.

The following discussion describes spent nuclear fuel and high-level radioactive waste, including mixed-oxide fuel (a mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors) and immobilized plutonium forms. The discussion also identifies other waste forms,

particularly Greater-Than-Class-C wastes and Special-Performance-Assessment-Required wastes, that are currently classified as low-level radioactive wastes but that could require disposal in a monitored geologic repository.

1.2.1 GENERATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

The material used to power commercial nuclear reactors typically consists of cylindrical fuel pellets made of uranium oxide. Fuel pellets are placed in tubes that are ordinarily about 3.7 meters (12 feet) long and 0.64 centimeter (0.25 inch) in diameter. Sealed tubes with fuel pellets inside them are called fuel rods (Appendix A). Fuel rods are arranged in bundles called fuel assemblies (see Figure 1-2), which are placed in a reactor.

In the reactor, neutrons from the fuel strike other uranium atoms, causing them to split into parts, and producing heat, radioactive fission products, and more free neutrons. This splitting of atoms is a form of nuclear reaction called *fission*. The neutrons produced by the fission process sustain the nuclear reaction by striking other uranium atoms in the fuel pellets, causing additional atoms to split. Control of the configuration and machinery associated with the fuel assemblies provides control of the rate at which fission occurs and, consequently, the amount of heat produced.

In a commercial power reactor, the heat that fission produces is used to convert water to steam. The steam turns turbine generators to produce electric energy. The reactors that power many naval vessels use the steam primarily to turn turbines to provide ship propulsion. Some research reactors also use the steam produced to generate electricity.

After a period in operation, enough of the fissile uranium atoms have undergone fission that the fuel is said to be "spent"; some of these spent nuclear fuel assemblies must be replaced with fresh fuel for operation to continue. During replacement, fresh fuel is placed in the reactor and spent fuel is placed in a pool of water. In commercial reactors, typical fuel cycles run 18 to 24 months, after which 25 to 50 percent of the spent nuclear fuel is replaced.

Nuclear reactor operators initially store spent nuclear fuel under water in spent fuel pools because of high levels of radioactivity and heat from decay of radionuclides. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground dry storage in an independent installation. Twenty-six sites have existing or planned independent above-ground dry storage facilities. Dry storage includes the storage of spent nuclear fuel at reactor sites in approved storage casks.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. All of these reactors have been shut down for several years. When defense plutonium production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and generate plutonium. DOE used chemical processes (called *reprocessing*) to extract plutonium and other materials from spent nuclear fuel for defense purposes. One of the chemical byproducts remaining after reprocessing is high-level radioactive waste. The reprocessing of limited quantities of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university research reactor fuels has also produced high-level radioactive waste.

Concerns about safety and environmental hazards contributed to DOE decisions to shut down parts of the weapons production complex in the 1980s. The shutdown, which became permanent due primarily to the reduced need for weapons materials at the end of the Cold War, included both production reactors and

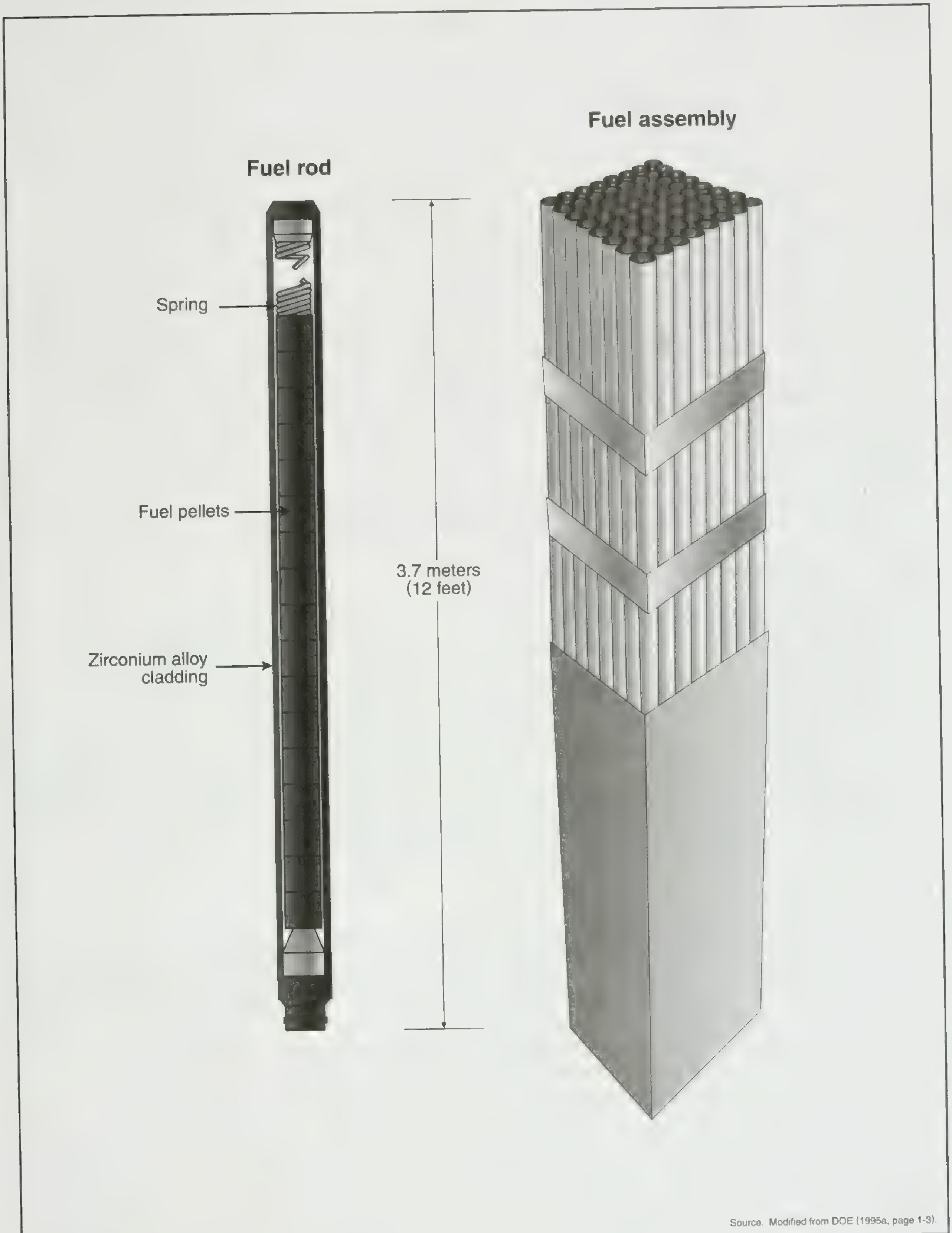


Figure 1-2. Typical nuclear fuel assembly and rod.

spent fuel reprocessing facilities. As a result, not all DOE spent nuclear fuel was reprocessed. Some of this fuel is now stored at DOE sites.

1.2.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor following irradiation, provided that the constituent elements of the fuel have not been separated by reprocessing. Commercial spent nuclear fuel comes from nuclear reactors operated to produce electric power for domestic use. DOE manages spent nuclear fuel from DOE defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. Most nuclear fuel is encased in highly corrosion-resistant cladding before being placed in a reactor. The fuel remains in the cladding after it is irradiated and withdrawn as spent nuclear fuel. The purpose of the cladding is to protect its contents in operating conditions associated with a reactor, which can reach temperatures of around 370°C (700°F) and pressures of 1.4 million kilograms per square meter (2,000 pounds per square inch) (Appendix A). Cladding, if it is not damaged or corroded, has the capability to isolate the spent nuclear fuel and delay the release of radionuclides to the environment for long periods.

Spent nuclear fuel is intensely radioactive in comparison to nonirradiated fuel and would be the primary source of radioactivity and heat generation in the proposed repository.

1.2.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel typically consists of uranium oxide fuel (which also contains actinides, fission products, and other materials), the cladding that contains the fuel, and the assembly hardware. The cladding for nuclear fuel assemblies is normally made of a zirconium alloy. However, about 1 percent of the spent nuclear fuel included in the Proposed Action is clad in stainless steel (Appendix A).

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the United States. Figure 1-1 shows the locations of these sites. Appendix A, Section A.2.1, provides details on spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site. Mixed-oxide fuel would be part of the commercial spent nuclear fuel inventory for the proposed repository. Section 1.2.4 includes a discussion of mixed-oxide fuel.

1.2.2.2 DOE Spent Nuclear Fuel

DOE spent nuclear fuel, like commercial spent nuclear fuel, has been withdrawn from a reactor following irradiation. Much of the DOE spent nuclear fuel is associated with past operations of reactors at the Hanford and Savannah River Sites that previously produced material for DOE's defense programs and research and development programs. These reactors are no longer operating. Smaller quantities of spent nuclear fuel have resulted from experimental reactor operations and from research conducted by approximately 55 university- and government-owned test reactors. DOE spent nuclear fuel also includes spent fuel from reactors on nuclear-powered naval vessels and naval reactor prototypes.

DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is currently stored at the Fort St. Vrain dry storage facility in Colorado and the West Valley site in New York, a site presently owned by the New York State Energy Research and Development Authority (see Figure 1-1). Additional small quantities remain at other locations. With the exception of Fort St. Vrain, which will retain its spent

nuclear fuel in dry storage until disposition. DOE plans to ship all of the spent nuclear fuel for which it is responsible from other sites to one of the three primary locations mentioned above for storage and preparation for ultimate disposition [discussed in DOE (1995b, all)]. This EIS does not analyze consolidation of spent nuclear fuel at DOE sites (see DOE 1995a, all). Appendix A, Section A.2.2, provides details on DOE spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

1.2.3 HIGH-LEVEL RADIOACTIVE WASTE

DOE stores high-level radioactive waste in below-grade tanks at the Hanford Site, the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and West Valley (see Figure 1-1 for locations). High-level radioactive waste can be in a liquid, sludge, or saltcake form, and a solid immobilized glass form (see below). Liquid waste consists of water and organic compounds that contain dissolved salts. Sludge is a mixture of insoluble (that is, materials that will not dissolve in tank liquid) metallic salt compounds that precipitated and settled out of the solution after the waste became alkaline. Saltcake is primarily sodium and aluminum salt that crystallized from the solution following evaporation. High-level radioactive waste can also include other highly radioactive material that the Nuclear Regulatory Commission determines by rule to require permanent isolation (Nuclear Waste Policy Act definitions, Section 12), as well as immobilized plutonium waste forms. Appendix A, Section A.2.3, provides details on high-level radioactive waste and discusses the amount currently stored and projected to be stored at each site. Included in this total is immobilized high-level radioactive waste that would result from the proposed electrometallurgic treatment of DOE sodium-bonded nuclear fuel at Argonne National Laboratory-West on the Idaho National Engineering and Environmental Laboratory site. DOE is preparing an EIS (64 *FR* 8553, February 22, 1999) to help it decide the disposition of this sodium-bonded fuel.

The DOE process for preparing high-level radioactive waste for disposal starts with the transfer of the waste from storage tanks to a treatment facility. Treatment ordinarily includes separation of the waste into high-activity and low-activity fractions, followed by vitrification of the high-activity fraction. Vitrification involves adding materials to the waste and heating the mixture until it melts. The melted mixture is poured into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass forms have been developed to keep the waste stable, confined, and isolated from the environment when inserted into disposal containers and disposed of in a monitored geologic repository. DOE will store the solidified high-level radioactive waste on the sites in canisters (see Figure 1-3) before eventual shipment to a repository.

DOE has begun to solidify and immobilize waste at the Savannah River Site and West Valley and plans to begin solidification and immobilization at Hanford. DOE is preparing an EIS (62 *FR* 49209, September 19, 1997) to help it determine the method it will use to solidify and immobilize high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory.

1.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has declared 50 metric tons (55 tons) of weapons-usable plutonium to be surplus to national security needs. This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium (Appendix A). DOE currently stores these plutonium-containing materials at the Pantex Plant, the Rocky Flats Environmental Technology Site, the Savannah River Site, the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the Oak Ridge, Los Alamos, and Lawrence Livermore National Laboratories.

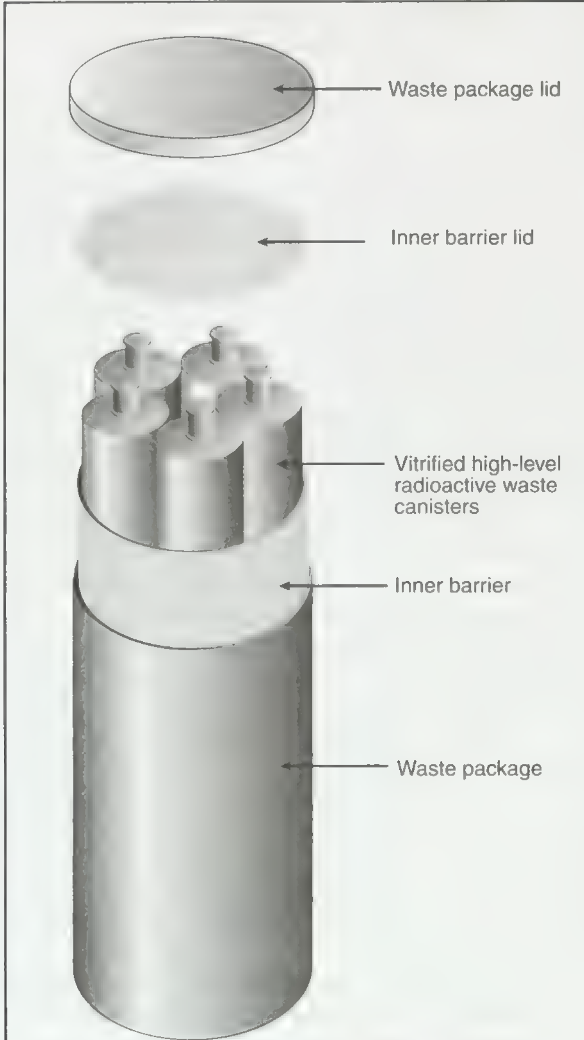


Figure 1-3. Vitrified high-level radioactive waste canisters in waste package.

DOE could emplace surplus weapons-usable plutonium in the repository in two forms. One form would be an immobilized plutonium ceramic that DOE would dispose of as high-level radioactive waste. The second form would be mixed uranium and plutonium oxide fuel (called mixed-oxide fuel) assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel. The analysis in this EIS assumed that approximately 18 metric tons (20 tons) of surplus plutonium would be immobilized plutonium and approximately 32 metric tons (35 tons) would be mixed-oxide spent nuclear fuel (Appendix A). The final waste forms would be immobilized plutonium and spent mixed-oxide fuel. The actual split could include the immobilization of between 18 and 50 metric tons (20 and 55 tons). Appendix A, Section A.2.4, contains details on sources, generation and storage status, and material characteristics of this surplus plutonium, and other high-level radioactive waste forms (for example, electrometallurgically treated sodium-bonded fuel).

1.2.5 OTHER WASTE TYPES WITH HIGH RADIONUCLIDE CONTENT

The Nuclear Regulatory Commission classifies most low-level radioactive waste into Classes A, B, and C (10 CFR Part 61), which reflect increasing levels of radioactivity. *Greater-Than-Class-C* is the term for radioactive waste generated by commercial activities that exceeds Nuclear Regulatory Commission concentration limits for Class C waste, as specified in 10 CFR Part 61. The Nuclear Regulatory Commission has determined that shallow land burial of Greater-Than-Class-C low-level radioactive waste generally is not acceptable. *Special-Performance-Assessment-Required* waste is DOE-generated low-level radioactive waste with radioactive content higher than Class C shallow land disposal limits.

1.3 National Effort To Manage Spent Nuclear Fuel and High-Level Radioactive Waste

This section provides background information on the management of spent nuclear fuel and high-level radioactive waste, and describes the Nuclear Waste Policy Act and its amendments.

1.3.1 BACKGROUND

In the late 1950s, active investigation began on the concept of mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. In the 1970s, the United States reprocessed a small

amount of commercial spent nuclear fuel to extract plutonium and studied the feasibility of expanded reprocessing. The plutonium would have been combined with uranium and used again as reactor fuel, substantially reducing the total amount of new enriched uranium required (NRC 1976, all). President Carter cancelled consideration of this approach, leaving disposal as a primary option for spent nuclear fuel.

In a February 12, 1980, message to Congress, President Carter stated that the safe disposal of radioactive materials generated by both defense and civilian nuclear activities is a national responsibility. In fulfillment of that responsibility, he announced a comprehensive program for the management of radioactive materials and adopted an interim planning strategy focusing on "the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel" (DOE 1980, page 2.7). President Carter stated that he would reexamine this interim strategy and decide if changes were required after the completion of the environmental reviews required by the National Environmental Policy Act. As part of this reexamination, DOE issued the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DOE 1980, all). That EIS analyzed the environmental impacts that could occur if DOE developed and implemented various technologies for the management and disposal of spent nuclear fuel and high-level radioactive waste. It examined several alternatives, including mined geologic disposal, very deep hole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. The 1981 Record of Decision for that EIS announced the DOE decision to pursue the mined geologic disposal alternative for the disposition of spent nuclear fuel and high-level radioactive waste (46 *FR* 26677, May 14, 1981).

1.3.2 NUCLEAR WASTE POLICY ACT

In 1982, Congress enacted the Nuclear Waste Policy Act (Public Law 97-425; 96 Stat 2201), which acknowledged the Federal Government's responsibility to provide permanent disposal of the nation's spent nuclear fuel and high-level radioactive waste, and established the Office of Civilian Radioactive Waste Management, which has the responsibility to carry out the evaluative, regulatory, developmental, and operational activities the Act assigns to the Secretary of Energy. The Nuclear Waste Policy Act began a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process (shown in Figure 1-4), DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites in May 1986. DOE recommended three of the five sites (Deaf Smith County, the Hanford Site, and Yucca Mountain) for possible study as repository site candidates, and President Reagan approved the three as candidates. In addition, the Nuclear Waste Policy Act recognized a need to ensure that spent nuclear fuel and high-level radioactive waste now accumulating at commercial and DOE sites do not adversely affect public health and safety and the environment [NWPA, Section 111(a)(7)].

In 1987, Congress significantly amended the Nuclear Waste Policy Act. This Act, as amended (42 USC 10101 *et seq.*), which this EIS refers to as the NWPA, identified one of the three Presidentially approved candidate sites, Yucca Mountain, as the only site to be studied as a potential location for a geologic repository. Congress directed the Secretary of Energy to study the Yucca Mountain site and recommend whether the President should approve the site for development as a repository. Congress also required that a Final EIS accompany a Secretarial recommendation to approve the Yucca Mountain site to the President [NWPA, Section 114(a)(1)]. DOE is preparing this EIS to fulfill that requirement.

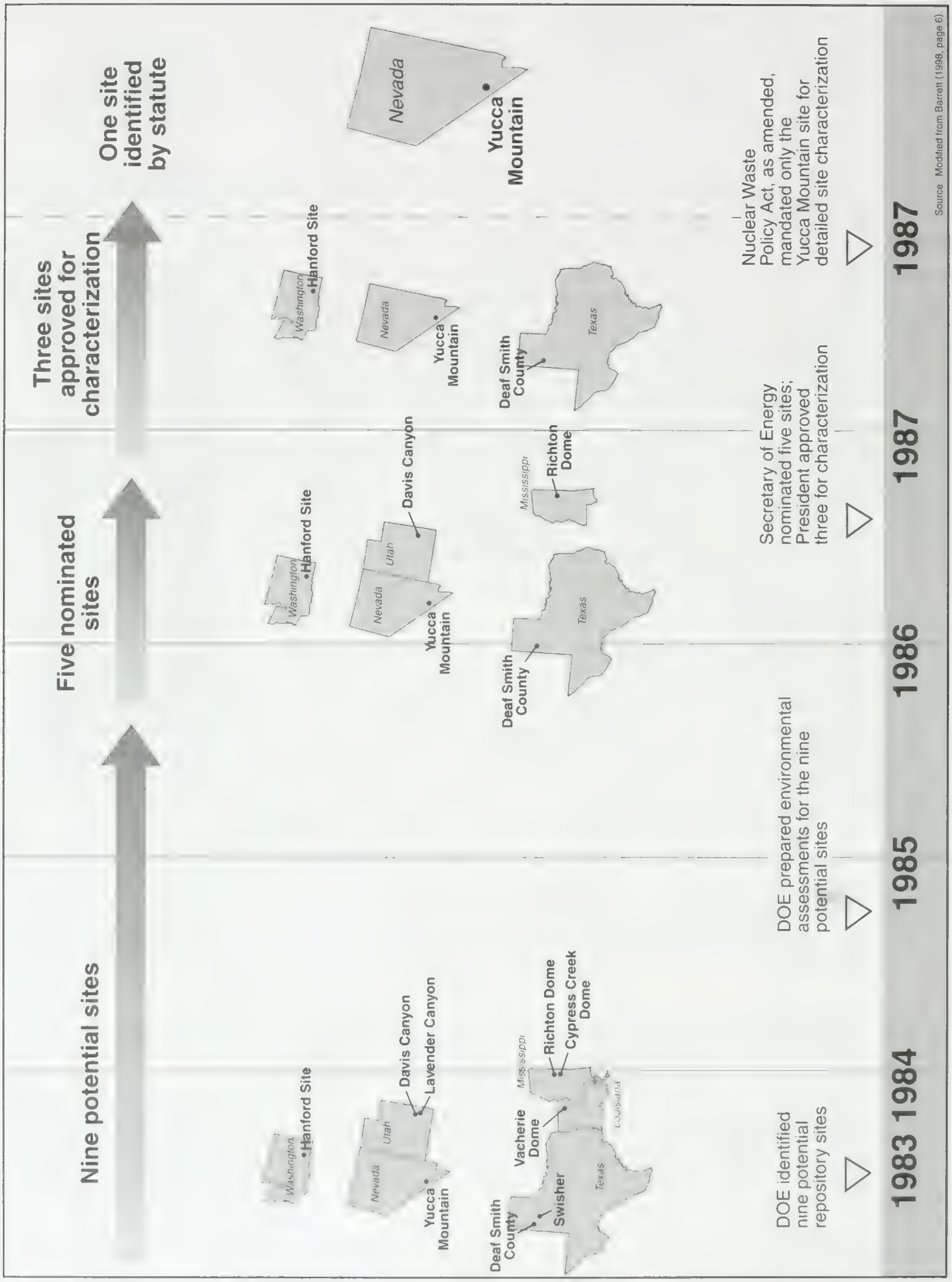


Figure 1-4. Events leading to selection of Yucca Mountain for study.

1.3.2.1 Requirement To Study and Evaluate the Site

In addition to the general responsibilities it establishes, the NWPA requires the Secretary of Energy specifically to characterize and evaluate the Yucca Mountain site for a geologic repository. The Act directs the Secretary of Energy to characterize only the Yucca Mountain site as a potential repository location and establishes a decisionmaking process to determine whether to designate Yucca Mountain as qualified for an application for repository construction authorization (NWPA, Sections 113, 114, 115, and 160).

Congress created the Nuclear Waste Technical Review Board as an independent organization to evaluate the technical and scientific validity of site characterization activities for the proposed repository and activities related to the packaging and transportation of spent nuclear fuel and high-level radioactive waste (NWPA, Section 503). The Nuclear Waste Technical Review Board must report findings, conclusions, and recommendations based on its evaluations to Congress and to the Secretary of Energy at least twice each year (NWPA, Section 508).

1.3.2.2 Elements of Site Evaluation

Sections 113, 114, and 115 of the NWPA contain specific and mostly sequential steps in the evaluation and decisionmaking process Congress has established for the Yucca Mountain site. The rest of this section and Section 1.3.2.3 describe that process.

The first steps in the evaluation and decisionmaking process for the Yucca Mountain site require the Secretary of Energy and, by extension, DOE, to gather data about Yucca Mountain and evaluate whether to recommend Yucca Mountain for approval as the site for a license application to the Nuclear Regulatory Commission for repository development. The Secretary's specific duties include:

- Undertake physical characterization of the Yucca Mountain site.

- Hold public hearings in the Yucca Mountain site vicinity.

- Prepare a description of the site, of spent nuclear fuel and high-level radioactive waste forms and packaging to be used, and of site safety.

- Make a recommendation to the President on whether to approve the site for development as a repository.

Section 1.4.3.3 describes the elements that the Secretary of Energy must develop and consider in making a site recommendation to the President and in providing a statement of the basis for that recommendation.

The NWPA directs the Secretary of Energy to evaluate a scenario under which DOE would place an inventory of material in the proposed Yucca Mountain Repository. This EIS considers a repository inventory of 70,000 metric tons of heavy metal (MTHM) comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE spent nuclear fuel and high-level radioactive waste. This overall inventory includes approximately 50 metric tons (55 tons) of surplus weapons-usable plutonium as spent mixed-oxide fuel and immobilized plutonium. Appendix A provides additional details of the inventory of materials.

To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used 0.5 MTHM per canister of defense high-level radioactive waste. DOE has used the 0.5-MTHM-per-canister approach since 1985. Using a different approach would change the

number of canisters of high-level radioactive waste in the Proposed Action. Regardless of the number of canisters, the impacts of the analysis would not significantly change because long-term repository performance results would be dominated by the spent nuclear fuel inventory. In addition, the EIS analyzes the impacts from the entire inventory of high-level radioactive waste in the cumulative impacts analysis.

Operating nuclear powerplants could generate approximately 105,000 MTHM through 2046. The total projected DOE inventory of materials includes 2,500 MTHM of spent nuclear fuel and approximately 22,280 canisters of high-level radioactive waste. Chapter 8 evaluates potential consequences of using a repository at Yucca Mountain to dispose of all spent nuclear fuel and high-level radioactive waste that could be produced through 2046 for which DOE retains ultimate responsibility.

1.3.2.3 Site Qualification and Authorization Process

The Nuclear Waste Policy Act, enacted by Congress in 1982 and amended in 1987, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The Nuclear Waste Policy Act, as amended (the EIS refers to the amended Act as the NWPA), also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. These hearings would be separate from the public hearings on the Draft EIS required under the National Environmental Policy Act. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will notify the Governor and legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

If, after the recommendation by the Secretary, the President considers the site qualified for an application to the Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the legislature submits a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. However, if the Governor or the legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

If the site designation became effective, the Secretary of Energy would submit to the Nuclear Regulatory Commission a License Application, based on a particular facility design, for a construction authorization no later than 90 days after the designation. The NWPA requires the Commission to adopt the Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

1.3.2.4 Environmental Protection and Approval Standards for the Yucca Mountain Site

Section 121 of the Nuclear Waste Policy Act of 1982 directed the U.S. Environmental Protection Agency to establish generally applicable standards to protect the general environment from offsite releases from radioactive materials in repositories and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress modified the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission in relation to a possible repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency to retain the National Academy of Sciences to conduct a study and issue findings and recommendations on setting reasonable standards for protecting public health and safety in relation to a repository at Yucca Mountain. Section 801(a) also directs the Environmental Protection Agency to establish Yucca Mountain-specific standards based on and consistent with the Academy's findings and recommendations. The standards will set health-based limits for any radioactive releases from a repository at Yucca Mountain. The National Academy of Sciences issued its findings and recommendations in a 1995 report (National Research Council 1995, all). The Environmental Protection Agency is in the process of establishing standards and is expected to place them in the Code of Federal Regulations (probably at 40 CFR Part 197). Chapter 11 contains a more detailed discussion of applicable regulations and other requirements.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the Environmental Protection Agency site-specific Yucca Mountain standards. The Nuclear Regulatory Commission has issued draft site-specific technical requirements and criteria (proposed 10 CFR Part 63). The Commission would use these requirements and criteria, when final, to evaluate an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

The Nuclear Waste Policy Act of 1982 required the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed site characterization. DOE issued these guidelines in 1984 (10 CFR Part 960). DOE is issuing this EIS before the Environmental Protection Agency and the Nuclear Regulatory Commission have completed their rulemaking processes and before DOE has determined whether to modify 10 CFR Part 960. The EIS provides current information on the proposed repository and presents an evaluation of the repository site, potential repository development, and anticipated repository performance measured against human health and other relevant technical criteria. DOE intends the results of the EIS evaluation to be useful for decisionmakers and to enhance the understanding and knowledge of members of the public.

1.4 Yucca Mountain Site and Proposed Repository

Spent nuclear fuel and high-level radioactive waste generate large amounts of radiation from the gradual decay of radioactive isotopes. These isotopes have the potential to cause severe human health impacts. In addition, the materials can generate heat from radioactive decay for periods lasting thousands of years. The Nuclear Waste Policy Act directs DOE to analyze and consider the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository.

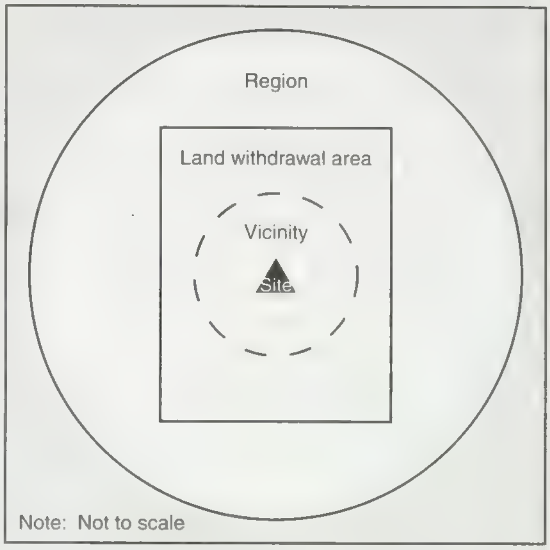
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



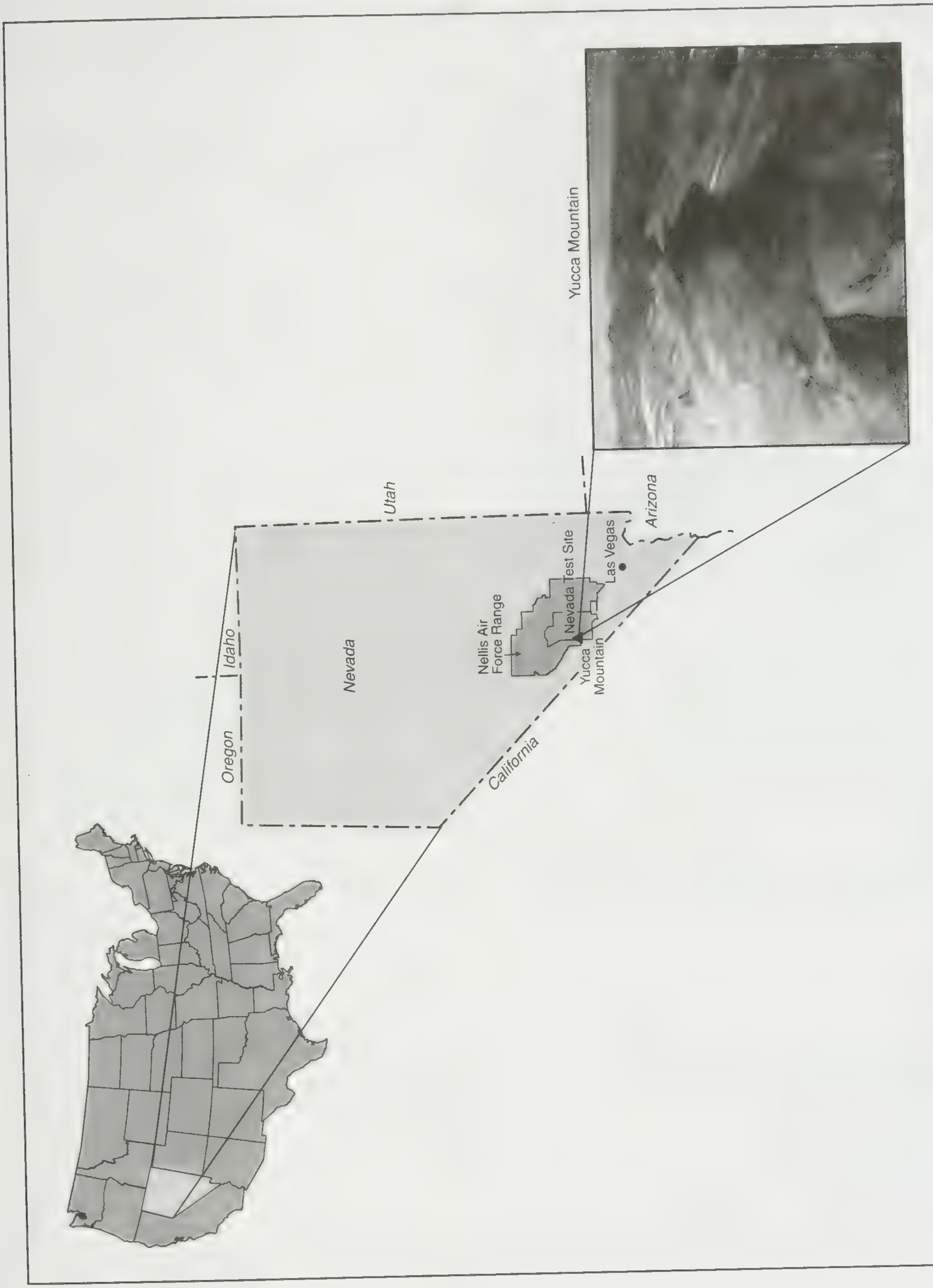
1.4.1 YUCCA MOUNTAIN SITE

The site of the proposed Yucca Mountain Repository (see Figure 1-5) is on lands administered by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The area surrounding the site is sparsely populated and receives an average of about 170 millimeters (7 inches) of precipitation per year. Chapter 3, Section 3.1, provides detailed information on the environment at the site.

The land withdrawal area analyzed in the EIS includes about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Department of Defense, and the U.S. Department of the Interior (see Figure 1-6). Approximately 3.5 square kilometers (1.4 square miles or 870 acres) comprising the repository site would be needed for development of surface repository facilities, with the remainder serving as a large buffer zone. If Yucca Mountain is recommended for development as a repository, all or a portion of the land withdrawal area would have to be withdrawn permanently from public access to satisfy Nuclear Regulatory Commission licensing requirements currently at 10 CFR 60.121. If the land to be withdrawn included land that this EIS does not consider for withdrawal, DOE would perform additional analysis as required by the National Environmental Policy Act.

1.4.2 PROPOSED DISPOSAL APPROACH

The proposed monitored geologic repository at Yucca Mountain would be a large underground excavation with a network of *drifts* (tunnels) serving as the emplacement area for spent nuclear fuel and high-level radioactive waste. Rail, legal-weight trucks, or heavy-haul trucks would provide most of the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to the repository. Barges could move spent nuclear fuel from some sites to rail and truck transfer points. Shippers would transport the materials in Nuclear Regulatory Commission-approved shipping containers designed to transport radioactive materials with minimal risk to the public health and safety and to the



Source: Modified from DOE (1998a, Overview, pages 10 and 11)

Figure 1-5. Yucca Mountain location.

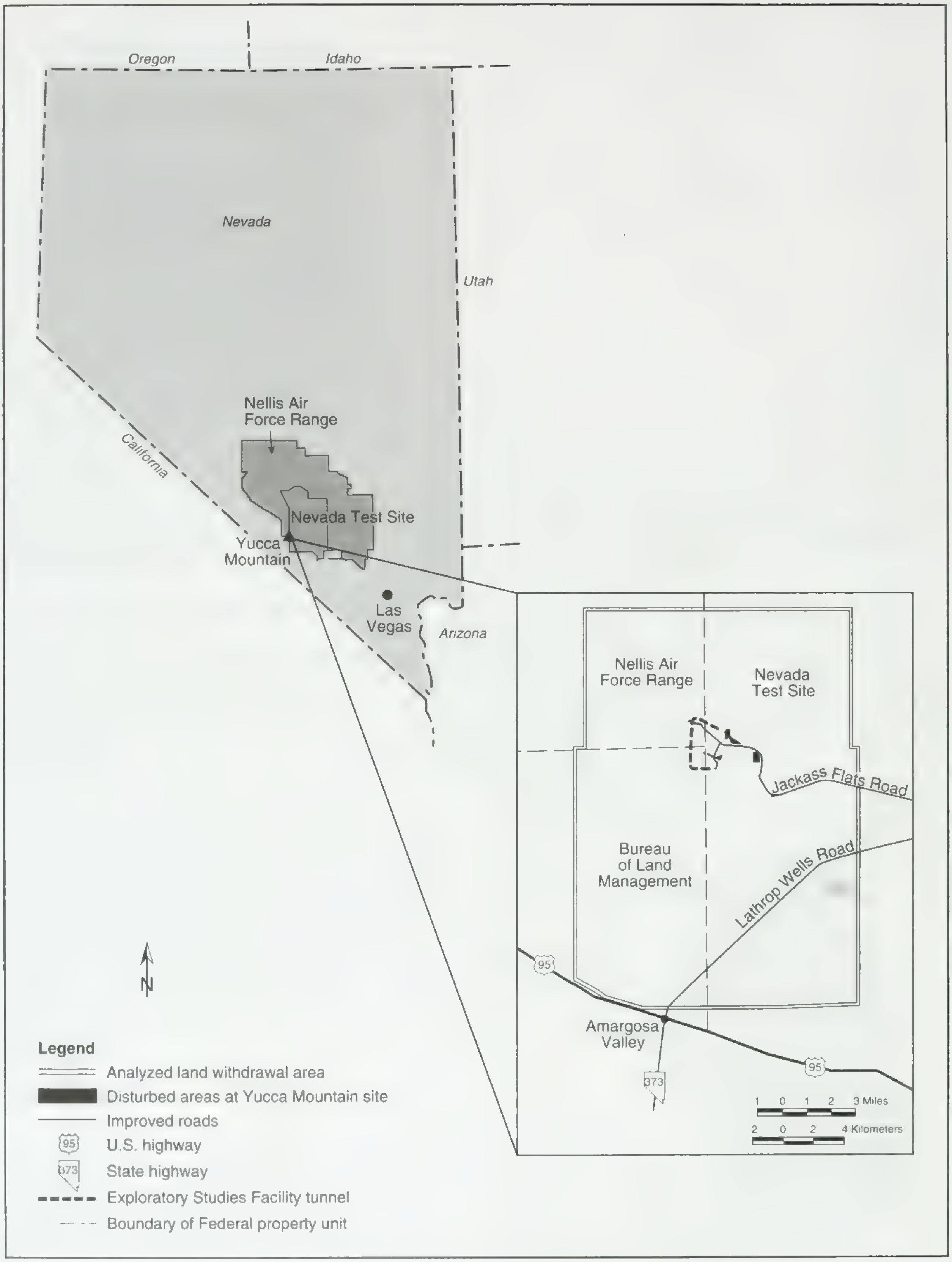


Figure 1-6. Land withdrawal area used for analytical purposes.

environment. (Chapter 6 discusses potential transportation systems.) Figure 1-7 shows the concept of temporary storage of spent nuclear fuel and high-level radioactive waste at storage sites, transporting these materials to the proposed repository, and disposing of the materials in an emplacement area.

At the repository, the material would be loaded in disposal containers. The filled disposal containers would be sealed, thereby becoming waste packages. The waste packages would be moved underground by rail. Remote-controlled handling vehicles would place the waste packages in emplacement drifts. The waste packages, which would be designed to remain intact for thousands of years (at a minimum), would be part of an engineered barrier system inside the mountain that would isolate spent nuclear fuel and high-level radioactive waste from the environment. The engineered barrier system, together with the geologic and hydrologic properties of the Yucca Mountain site, would ensure that a potential release of radioactive material after repository closure would meet applicable performance standards to contain and isolate the waste for 10,000 years or more. Chapter 5 provides detailed discussions of the natural system and of waste packages. Chapter 2 describes the Proposed Action at Yucca Mountain in additional detail, including the transportation activities required to move the spent nuclear fuel and high-level radioactive waste to the site.

Under the NWPA, the proposed repository, if authorized, would be a facility for the permanent disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. The Nuclear Waste Policy Act requires the Nuclear Regulatory Commission to include in the authorization a prohibition against the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Nuclear Waste Policy Act, Section 114(d)]. DOE has allocated 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM equivalent of DOE spent nuclear fuel and high-level radioactive waste to the proposed repository at Yucca Mountain. The Proposed Action that this EIS evaluates, therefore, includes the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to Yucca Mountain and the emplacement of as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the proposed repository. Chapter 8 of this EIS analyzes cumulative impacts from the disposal at Yucca Mountain of all spent nuclear fuel and high-level radioactive waste projected to be produced through 2046 for which DOE will retain ultimate responsibility. Chapter 8 also considers the disposal of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste at Yucca Mountain.

1.4.3 DOE ACTIONS TO EVALUATE THE YUCCA MOUNTAIN SITE

The primary evaluation activities related to the Yucca Mountain site that DOE has performed or will perform are site characterization studies, a Viability Assessment, and a potential Site Recommendation. The following sections address these activities.

1.4.3.1 Site Characterization Activities

In accordance with the NWPA [Section 113(b)], the DOE Office of Civilian Radioactive Waste Management prepared a Site Characterization Plan for the Yucca Mountain site (DOE 1988a, all). DOE has had an ongoing program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a potential geologic repository and to provide information for this EIS. The program consists of scientific, engineering, and technical studies and activities.

Examples of activities, investigations, and evaluations associated with site characterization include the following:

- Construction of an Exploratory Studies Facility, including the North and South Portal Ramps (openings into the mountain)

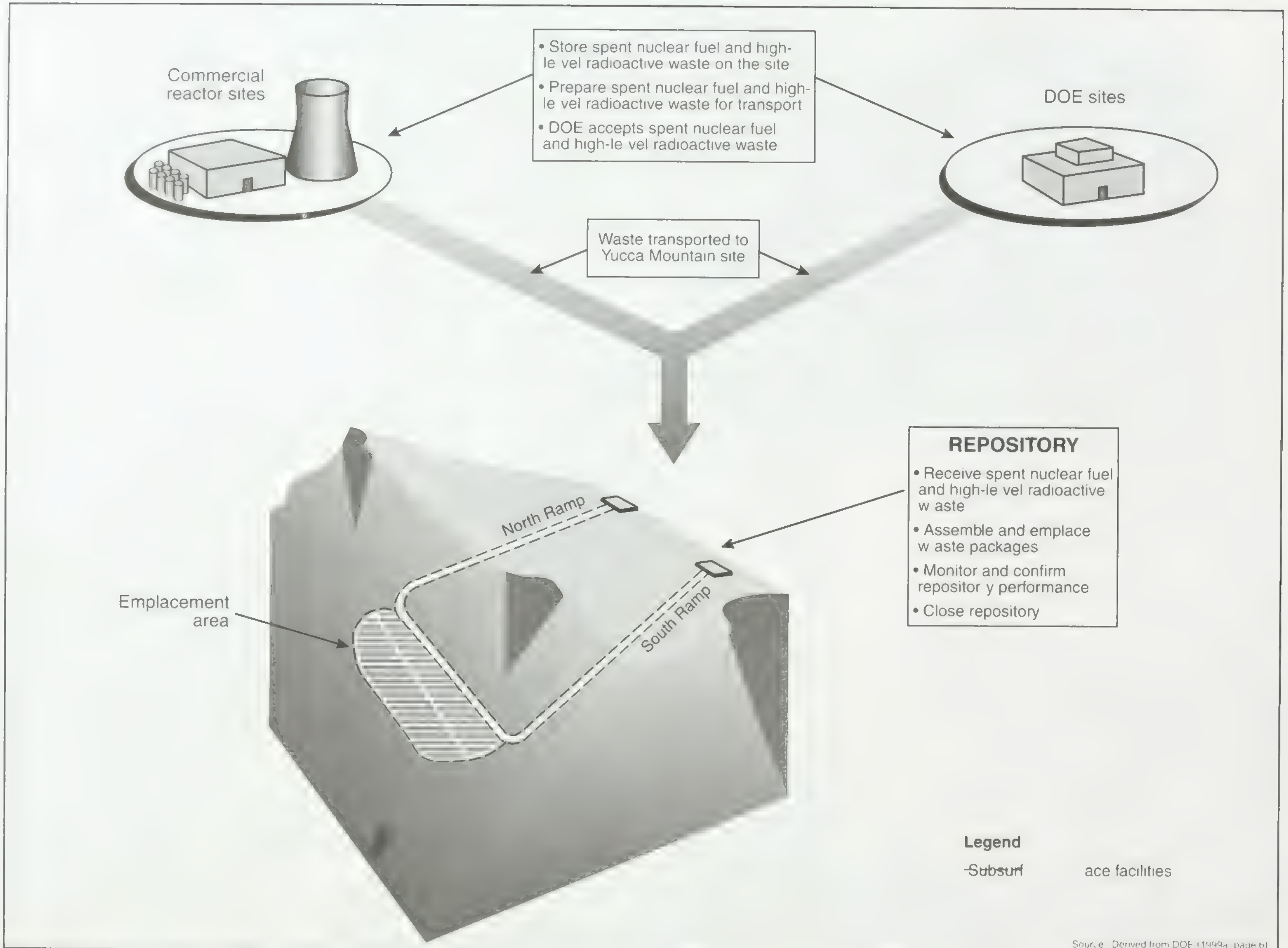


Figure 1-7. Spent nuclear fuel and high-level radioactive waste temporary storage, transportation, and disposal.

- Excavation of underground tunnels and rooms in the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments

- Investigations of such topics as hydrology, including groundwater characteristics; general site geology; and specific geologic issues such as erosion, seismicity, and volcanic activity

- Field monitoring, including air quality, meteorological, radiological, and water resources monitoring

- Cultural resources studies, including Native American interests

- Terrestrial ecosystem studies

1.4.3.2 Viability Assessment

Pursuant to the Energy and Water Development Appropriations Act for Fiscal Year 1997 (Public Law 104-206), DOE issued the *Viability Assessment of a Repository at Yucca Mountain* in December 1998 (DOE 1998a, all). The Viability Assessment provides information on the progress of the Yucca Mountain Site Characterization Project to Congress, the President, regulatory agencies, stakeholder organizations, and the general public. In addition, the Viability Assessment identifies issues to be addressed before the Secretary of Energy can make a recommendation to the President on whether to approve the site for development as a repository. Further, the Viability Assessment provides an understanding of Yucca Mountain's capability to contain and isolate spent nuclear fuel and high-level radioactive waste in the repository system and limit releases to the accessible environment. The Viability Assessment includes the following:

- The preliminary design concept for the critical elements of the repository and waste package

- A total system performance assessment, based on the design concept and the scientific data and analyses available by 1998, that describes the probable behavior of the repository in the Yucca Mountain geologic setting

- A plan and cost estimate for the remaining work required to complete and submit a License Application to the Nuclear Regulatory Commission

- An estimate of the costs to construct and operate the repository in accordance with the design concept

This EIS summarizes results from the Viability Assessment, where applicable (see Chapter 5), and data analyses that continued after the completion of the Viability Assessment.

TOTAL SYSTEM PERFORMANCE ASSESSMENT

The *total system performance assessment* is an analysis tool to evaluate one particular environmental impact—possible future radioactivity doses to people living near the proposed repository. If it occurred, this impact would take place thousands of years in the future. Therefore, calculations must be used, based on the best available knowledge today of future phenomena. The analysis brings together computer simulations of the processes in the natural and engineered components of the repository, transport of radioactive substances to the affected people via available pathways, and effects of these materials on people and the environment. Because we cannot know definitively what will happen, the analysis considers a range of possible inputs. Therefore, the results are statistical ranges of outcomes.

1.4.3.3 Site Recommendation

Section 114(a) of the Nuclear Waste Policy Act requires that the recommendation be based on the record of information developed during site characterization and be submitted to the President together with a comprehensive statement of the basis of that recommendation. The recommendation is to be supported by:

- A description of the proposed repository, including preliminary engineering specifications for the facility
- A description of the material forms or packaging proposed for use at the repository, and an explanation of the relationship between the forms or packaging and the geologic medium of the site
- A discussion of data obtained in site characterization activities that relate to the safety of the site
- A Final EIS prepared for the Yucca Mountain site accompanied by comments from the Secretary of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission
- The preliminary comments of the Nuclear Regulatory Commission on the extent to which the material form proposal and the at-depth site characterization analysis are sufficient for inclusion in a License Application
- The views and comments of the governor and legislature of any state and of the governing bodies of affected Native American tribes
- Any impact report submitted under Section 116(c)(2)(B) of the Nuclear Waste Policy Act, as amended, by the State of Nevada
- Other information the Secretary considers appropriate

1.4.3.4 No-Action Alternative

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site decommissioning and reclamation. The commercial utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, in a condition ready for shipment to a repository. The potential environmental impacts from two No-Action scenarios, described below, serve as a baseline to compare the potential environmental impacts of the Proposed Action.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites under institutional control for at least 10,000 years.
- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

DOE recognizes that neither scenario would be likely if there were a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a baseline for comparison to the Proposed Action. There are a number of possibilities that DOE could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of alternatives to deep geologic disposal. However, these potential actions are speculative.

1.5 Environmental Impact Analysis Process

The National Environmental Policy Act of 1969, as amended, and regulations promulgated by the Council on Environmental Quality established the procedures for Federal agencies to use when considering potential beneficial and adverse environmental consequences of proposed major Federal actions. This process requires Federal agencies to analyze potential impacts of proposed major Federal actions on the human and natural environments to assist the agencies in making informed decisions on those actions. A major emphasis of the EIS process is to promote public awareness of the proposed actions and provide opportunities for public involvement.

An agency prepares an EIS in a series of steps: (1) soliciting comments from Federal and state agencies, stakeholders, Tribal Nation representatives, and the general public to assist in defining the proposed action, alternatives, and issues requiring analysis (a process known as *scoping*); (2) preparing a Draft EIS for public distribution and comment; (3) receiving and responding to public comments on the Draft EIS; and (4) preparing a Final EIS that incorporates or summarizes (if the public comments are exceptionally voluminous) and responds to public comments on the Draft EIS. DOE conducted the scoping process for this EIS from August to December 1995 (see Section 1.5.1). After a public comment period on this Draft EIS, and after considering comments received, DOE will prepare a Final EIS. The Final EIS is scheduled for publication in August 2000.

The NWPA includes four specific provisions relevant to this EIS. Under the NWPA, the Secretary is not required to consider in this EIS (1) the need for a geologic repository, (2) the time at which a repository could become available, and (3) alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The fourth provision addresses the issue of potential alternative sites by providing that the EIS does not need to consider any site other than Yucca Mountain for repository development [NWPA, Section 114(f)(2) and (3)]. However, DOE has focused the EIS analysis on two alternatives: (1) the Proposed Action of constructing, operating and monitoring, and eventually closing a repository at Yucca Mountain, and (2) the No-Action Alternative, which assumes that site characterization activities at Yucca Mountain would end, resulting in spent nuclear fuel remaining at commercial sites and spent nuclear fuel and high-level radioactive waste remaining at DOE facilities.

1.5.1 NOTICE OF INTENT AND SCOPING MEETINGS

The EIS scoping process is intended to determine the scope and the significant issues to be analyzed in depth in the EIS. The scoping process must begin early and must be open, and must include public notice of public meetings and of the availability of environmental documents to inform those persons and agencies who might be interested in or affected by a proposed action.

On August 7, 1995, DOE published a Notice of Intent announcing that it would prepare an EIS for a proposed repository at Yucca Mountain, Nevada (60 *FR* 40164, August 7, 1995). To encourage broad participation by the public, before publishing the Notice of Intent DOE notified stakeholders, the media, Congressional representatives with jurisdiction over nuclear issues, the Nevada Congressional delegation, the Office of the Governor of Nevada, affected units of local government in the Yucca Mountain site vicinity, Native American tribes, the Nuclear Regulatory Commission, and the Nuclear Waste Technical

Review Board. The notification discussed the Proposed Action and No-Action Alternative, the proposed schedule of scoping meetings, and the means by which DOE intended to solicit public comments.

DOE representatives met with 13 Native American tribes and organizations to describe the EIS scoping process and to request tribal involvement in the process. In addition, DOE invited public interest groups, transportation interests, industry and utility organizations, regulators, and members of the general public to participate in the process. The Department mailed a series of information releases to Yucca Mountain stakeholders and members of the public notifying them of the opportunity to comment; submitted press releases and public service announcements to newspapers and television and radio stations; and made information about Yucca Mountain, the EIS, and the scoping process available to the public on the Internet (at *http://www.ymp.gov*) and in designated public reading rooms around the country. DOE solicited written comments and held 15 public scoping meetings across the country between August 29 and October 24, 1995, to enable interested parties to present comments on the scope of this EIS. The scoping period officially closed on December 5, 1995 (DOE 1997a, page 7).

PUBLIC SCOPING MEETING LOCATIONS

Sacramento, California
Denver, Colorado
College Park, Georgia (near Atlanta)
Boise, Idaho
Chicago, Illinois
Linthicum, Maryland (near Baltimore)
Kansas City, Missouri
Caliente, Nevada
Las Vegas, Nevada
Pahrump, Nevada
Reno, Nevada
Tonopah, Nevada
Troy, New York (near Albany)
Dallas, Texas
Salt Lake City, Utah

A total of 568 people submitted more than 1,000 comment documents during the public scoping period. DOE responded to these comments in the *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1997a, all).

DOE considered all comments received during the scoping process. Several of these comments led to changes in the analytical approach to the EIS. The two most notable changes were the consideration of additional inventories and the addition of new Nevada transportation route alternatives. A number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA; address DOE's responsibility to begin accepting waste in 1998 (including an analysis of the potential for receipt of spent nuclear fuel and high-level radioactive waste prior to the start of emplacement); describe the potential decisions that the EIS would support; and examine activities other than construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain.

Other concerns raised by the public during scoping emphasized that DOE needed to ensure that the EIS thoroughly addresses the impacts of constructing and operating a geologic repository and related facilities (including the use of a rail line, heavy-haul truck routes, and intermodal transfer stations) on:

- Land uses in the Yucca Mountain vicinity (including consistency with existing land-use plans)
- Regional air quality and meteorology
- Geology (including the effects of earthquakes and volcanism and the potential for transport of radioactive and hazardous materials from the repository)
- Regional hydrology (including groundwater quality in Amargosa Valley, Ash Meadows, and Death Valley National Park)

- Biological resources (including postclosure effects on wildlife from potential increased surface temperatures)
- Health and safety (including past radiation exposures from activities at the Nevada Test Site for both pre- and postclosure periods)
- Long-term performance assessment for the repository (including an evaluation of the ability of the overall system to meet potential performance objectives, waste package performance and degradation given different thermal loads, infiltration rates, corrosion models, and other relevant factors)
- Sabotage and safeguards and security measures during waste transport and disposal
- Cultural and historic resources and environmental justice
- Socioeconomics
- Mitigation (including the mitigation of impacts from both routine operations and accident conditions)

DOE included discussions and analyses in the EIS that respond to these public issues and concerns. In addition, DOE received many requests for more formal involvement in the EIS preparation process by representatives of the affected units of local government and Native American tribes. In response, DOE tasked (and funded) the American Indian Writers Subgroup to prepare a document setting forth Native American perspectives and views regarding the repository and Yucca Mountain; that document is quoted and referenced in the EIS. A similar opportunity was extended to the State of Nevada and the affected units of local government to prepare their own documents setting forth perspectives and views on a variety of issues of local and regional concern, which DOE agreed to incorporate by reference in the EIS. At Draft EIS publication, Nye County (Buqo 1999, all) had prepared such a document. In addition, other documents related to the Yucca Mountain region have been prepared in the past by several local government units including Clark, Lincoln, and White Pine Counties.

Many other public scoping comments presented views and concerns not related to the scope or content of the Proposed Action. Examples of such comments include statements in general support of or opposition to Yucca Mountain, repositories, and nuclear power; lack of public confidence in the Yucca Mountain program; inequities and political aspects of the siting process by which Yucca Mountain was selected for further study by Congress; the constitutional basis for waste disposal in Nevada; psychological costs or effects; risk perception and stigmatization; legal issues involving Native American land claims and treaty rights; and unrelated DOE activities. DOE considered and recorded these concerns in the comment summary document on the scoping process (DOE 1997a, all), but has not included analyses of these issues in the EIS.

1.5.1.1 Additional Inventory Studies

The Proposed Action is to construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. During the scoping period, DOE received many comments that noted the potential existence of more than 70,000 MTHM of these materials and encouraged DOE to evaluate the total projected inventory. For example, presently operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel eligible for disposal by 2046 if all commercial licenses were extended. In addition, some commenters requested that the EIS evaluate the disposal of radioactive waste types that might require permanent isolation, such as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste. For these reasons, DOE has included in the EIS cumulative impact analysis an evaluation of the

cumulative environmental impacts that could occur as a result of the disposal of all projected spent nuclear fuel and high-level radioactive waste and the disposal of quantities of Greater-Than-Class-C and Special-Performance-Assessment-Required waste in the Yucca Mountain Repository (see Chapter 8).

1.5.1.2 Additional Nevada Transportation Analyses

In response to public comments, DOE decided to analyze a fifth branch rail line and a fifth route for heavy-haul trucks in Nevada. The Department added analyses of the Caliente-Chalk Mountain branch rail line and the Caliente-Chalk Mountain route for heavy-haul trucks to the analyses of four rail corridors and four heavy-haul routes it had previously identified for potential transportation impacts in Nevada. Chapter 6 and Appendix J describe the transportation analyses. The U.S. Air Force opposes the use of the Caliente-Chalk Mountain rail corridor and heavy-haul truck route because of national security concerns; at this time DOE regards these routes as nonpreferred alternatives.

APPROXIMATE WASTE INVENTORIES
(Measurement methods differ among waste types)

Commercial spent nuclear fuel
- Projected total: 105,000 MTHM in 2046
- Current disposal plan: 63,000 MTHM (includes as much as 32 metric tons of plutonium disposed of as mixed oxide spent nuclear fuel)

DOE spent nuclear fuel
- Projected total: 2,500 MTHM
- Current disposal plan: 2,333 MTHM (one-third of the 7,000-MTHM total of DOE material proposed for disposal, which includes high-level radioactive waste)

High-level radioactive waste
- Projected total: 22,280 canisters (would include as much as 50 metric tons of immobilized plutonium)
- Current disposal plan: 8,315 canisters (includes 18 metric tons of immobilized plutonium)

Greater-Than-Class-C waste
- Projected total: 2,100 cubic meters
- Disposal evaluated in Chapter 8

Special-Performance-Assessment-Required waste
- Projected total: 4,000 cubic meters
- Disposal evaluated in Chapter 8

1.5.2 CONFORMANCE WITH DOCUMENTATION REQUIREMENTS

DOE has performed formal documented reviews of data to identify gaps, inconsistencies, omissions, or other conditions that would cause data to be suspect or unusable.

DOE planned analyses to ensure consistency and thoroughness in the environmental studies conducted for this EIS. DOE has also used configuration control methods to ensure that EIS inputs are current, correct, and appropriate, and that outputs reflect the use of appropriate inputs.

All work products for this EIS have undergone documented technical, editorial, and managerial reviews for adequacy, accuracy, and conformance to project and DOE requirements. Work products related to impact analyses (for example, calculations, data packages, and data files) have also undergone formal technical and managerial reviews. Calculations (manual or computer-driven) generated to support impact analyses have been verified independently and completely in accordance with project management procedures.

1.5.3 RELATIONSHIP TO OTHER ENVIRONMENTAL DOCUMENTS

A number of completed, in-preparation, or proposed DOE National Environmental Policy Act documents relate to this EIS. In addition, other Federal agencies have prepared related EISs. As directed by the Council on Environmental Quality regulations that implement the National Environmental Policy Act,

DOE has used information from these documents in its analysis and has incorporated this material by reference as appropriate throughout this EIS. Table 1-1 lists the documents that formed a basis for decisions associated with a geologic disposal program and investigation of Yucca Mountain as a potential repository site; these include the EIS for Management of Commercially Generated Radioactive Waste (DOE 1980, all), the Surplus Plutonium Disposition Draft EIS (DOE 1998b, all), and the Yucca Mountain Site Environmental Assessment (DOE 1986a, all).

Table 1-1. Related environmental documents[a] (page 1 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities		
Final EIS, Management of Commercially Generated Radioactive Waste (DOE 1980, all)	Commercial SNF; DOE SNF and HLW	Examines different disposal alternatives. ROD documented DOE decision to pursue geologic disposal for SNF and HLW.
EA, Yucca Mountain Site, Nevada Research and Development Area (DOE 1986a, all)	Commercial SNF; DOE SNF and HLW	Examines impacts of site characterization activities and possible geologic repository at Yucca Mountain.
Final Supplemental EIS, Defense Waste Processing Facility, Savannah River Site, Aiken, South Carolina (DOE 1994a, all)	HLW	Examines impacts of constructing and operating DWPF, which processes HLW at SRS. SRS HLW could be eligible for repository disposal.
Final EIS, Waste Management, Savannah River Site (DOE 1995c, all)	HLW	Examines impacts of managing five types of waste (including liquid HLW) at SRS over 10 years. SRS HLW could be eligible for repository disposal.
Final EIS, Interim Management of Nuclear Materials at the Savannah River Site (DOE 1995d, all)	HLW	Examines impacts of stabilization and interim storage of plutonium, uranium, and other nuclear materials. SRS SNF and HLW could be eligible for repository disposal.
Final EIS, Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington (DOE 1996a, all)	DOE SNF	Examines impacts of managing SNF in K-Basins at Hanford. Hanford SNF could be eligible for repository disposal.
Draft EIS, Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center (DOE 1996b, all)	HLW	Examines impacts of solidifying liquid HLW obtained from reprocessing commercial SNF. WVDP HLW could be eligible for repository disposal.
Final EIS, Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DOE 1996c, all)	DOE SNF	Examines impacts of managing SNF from foreign research reactors in accordance with U.S. policy to reduce nuclear weapons proliferation. SNF from foreign research reactors stored at SRS and INEEL could be eligible for repository disposal.
Final EIS, Hanford Site Tank Waste Remediation System (DOE 1996d, all)	HLW	Examines impacts of long-term management and disposal of Hanford tank waste, including HLW. Hanford HLW could be eligible for repository disposal.
Draft EIS, Surplus Plutonium Disposition (DOE 1998b, all)	Plutonium	Examines the alternatives for and impacts of disposition of 50 metric tons (55 tons) of surplus plutonium. Ultimate disposition of the plutonium could involve repository disposal.

Table 1-1. Related environmental documents[a] (page 2 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities (continued)		
Supplement to the Surplus Plutonium Disposition Draft Environmental Impact Statement (DOE 1999b, all)	Plutonium	Examines potential environmental impacts of using mixed oxide fuel in six reactors as well as program changes made since the publication of the Draft EIS.
Draft EIS, Idaho High-Level Waste and Facilities Disposition (in preparation)	HLW	Examines impacts of treatment, storage, and disposal of INEEL HLW and facilities disposition. INEEL HLW could be eligible for repository disposal.
Draft EIS, Savannah River Site Spent Nuclear Fuel Management (DOE 1998c, all)	DOE SNF	Examines impact of several technologies for management of SNF at SRS, including placing these materials in forms suitable for ultimate disposition. Information from this EIS aids the study of packaging, transportation, and disposition of SNF.
Record of Decision (USN 1997a, all) and the Second Record of Decision (USN 1997b, all) for a Container System for the Management of Naval Spent Nuclear Fuel Final EIS (USN 1996a, all)	DOE SNF	Evaluates potential impacts of using alternative container systems for management of naval SNF following examination at INEEL. Naval SNF processed and stored at INEEL could be eligible for repository disposal. DOE used information from this EIS to estimate impacts from manufacture of disposal containers and shipping casks.
Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at INEEL (DOE 1999e, all)	DOE SNF	Determines the use of a multipurpose canister or comparable system for the management of DOE SNF at INEEL that might be suitable for shipment using existing transportation casks.
Record of Decision for a Multi-Purpose Canister or Comparable System for Idaho National Engineering and Environmental Laboratory Spent Nuclear Fuel (DOE 1999f, all)	DOE SNF	Evaluates the impacts of using dual-purpose canisters to prepare DOE SNF located at INEEL for interim storage and transport outside the State of Idaho.
Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report NUREG-1437 (NRC 1996, all) and the Draft Supplement for the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Addendum 1 (NRC 1999, all)	Commercial SNF	Addresses the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, Nevada, and the impacts of transporting higher-burnup fuel.
Programmatic examination of waste management		
Record of Decision (DOE 1995b, all) for the Final Programmatic EIS, Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs (DOE 1995a, all)	DOE SNF	Examines programmatic impacts of storage of DOE SNF that could be eligible for repository disposal. In the associated ROD, DOE decided where DOE SNF would be managed.
Final Programmatic EIS, Storage and Disposition of Weapons-Usable Fissile Materials (DOE 1996e, all)	DOE SNF and HLW	Examines impacts of long-term storage of plutonium and highly enriched uranium at several DOE sites. Spent mixed-oxide fuel and immobilized plutonium could be eligible for repository disposal.
Final Programmatic EIS, Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DOE 1997b, all)	HLW	Examines impacts of managing five types of waste at DOE sites. Examines storage of HLW canisters and transportation of HLW canisters between DOE sites and Yucca Mountain.

Table 1-1. Related environmental documents[a] (page 3 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Programmatic examination of waste management (continued)		
Final EIS, Nevada Test Site and Off-Site Locations in the State of Nevada (DOE 1996f, all)		Examines potential impacts of future mission activities at NTS. DOE used information from NTS EIS for Yucca Mountain site description and environmental impacts of NTS waste management activities. Cumulative impact analysis included activities analyzed in NTS EIS.
Regional description and cumulative impact information		
Final EIS, Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station Fallon, Nevada (USN 1998, all)		Examines impacts of land withdrawal around Naval Air Station Fallon. Repository EIS analysis of cumulative impacts considered proposed actions at Naval Air Station Fallon.
Legislative EIS for Nellis Air Force Range Renewal (USAF 1999, all)		Examines impacts of renewal of land withdrawal for Nellis Air Force Range. Yucca Mountain site is partly on range, and Repository EIS considers proposed actions at Nellis in its cumulative impacts analysis.
Proposed Caliente Management Framework Plan Amendment and FEIS for the Management of Desert Tortoise Habitat (BLM 1999a, all)		Examines the implementation of BLM management goals and actions for the administration of the desert tortoise habitat in Lincoln County, Nevada.
Final EIS for the Cortez Pipeline Gold Deposit (BLM 1996, all)		Examines potential for impacts from mining-related activities at a location in western Nevada.
EA, Pipeline Infiltration Project (BLM 1999b, all)		Examines potential for impacts from mining-related activities at a location in western Nevada.
Environmental Impact Analysis process for a Draft Secretarial Report to Congress regarding a proposal to establish permanent Timbisha Shoshone Tribal land use in and around Death Valley National Park (64 *FR* 19193 to 19194, April 19, 1999)		Examines the potential for impacts from creating a Timbisha Shoshone Tribal reservation in and around Death Valley National Park.

a. Abbreviations: BLM = Bureau of Land Management; DOE = U.S. Department of Energy; DWPF = Defense Waste Processing Facility; EA = environmental assessment; EIS = environmental impact statement; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory; NTS = Nevada Test Site; ROD = Record of Decision; SNF = spent nuclear fuel; SRS = Savannah River Site; WVDP = West Valley Demonstration Project.

2

Proposed Action and No-Action Alternative

2. PROPOSED ACTION AND NO-ACTION ALTERNATIVE

Under the Proposed Action, the U.S. Department of Energy (DOE) would construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain (see Section 2.1). The Proposed Action includes transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site (see Figure 2-1).

Under the No-Action Alternative (see Section 2.2), DOE would end site characterization activities at Yucca Mountain, and the commercial and DOE sites would continue to manage their spent nuclear fuel and high-level radioactive waste (see Figure 2-1). The No-Action Alternative assumes that spent nuclear fuel and high-level radioactive waste would be treated and packaged as necessary for its safe onsite management. DOE does not intend to represent the No-Action Alternative as a viable long-term solution but rather to use it as a baseline against which the Proposed Action can be evaluated.

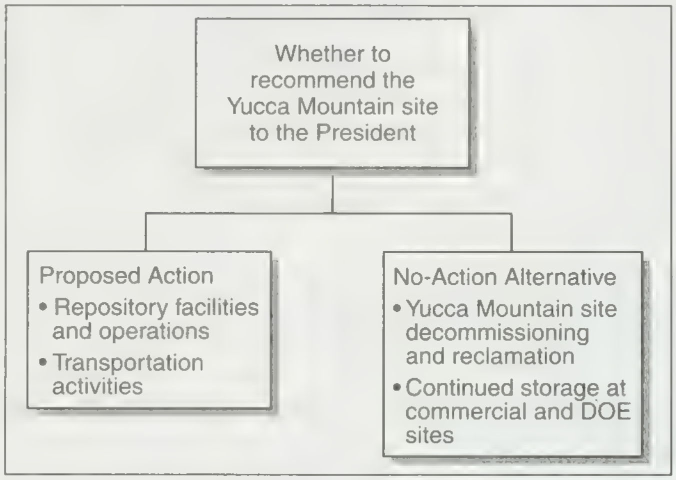


Figure 2-1. General activity areas evaluated under the Proposed Action and No-Action Alternative.

Section 2.3 discusses the alternatives that DOE considered but eliminated from detailed study in this environmental impact statement (EIS). Section 2.4 summarizes findings from the EIS and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative. Section 2.5 addresses the collection of information and analyses performed for the EIS. Section 2.6 identifies the preferred alternative.

DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste.

As part of the Proposed Action, the EIS analyzes the impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

2.1 Proposed Action

DOE proposes to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. About 600 square

kilometers (230 square miles or 150,000 acres) of land in Nye County, Nevada, could be permanently withdrawn from public access for DOE use for the repository (see Figure 2-2 for location of area). DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the inherent, natural geologic features of the mountain and engineered (manmade) barriers to ensure the long-term isolation of the waste from the human environment. DOE would build the repository inside Yucca Mountain between 200 and 425 meters (660 and 1,400 feet) below the surface and between 175 and 365 meters (570 and 1,200 feet) above the water table.

Under the Proposed Action, DOE would permanently place approximately 10,000 to 11,000 waste packages containing no more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in the repository. Of the 70,000 MTHM to be emplaced in the repository, 63,000 MTHM would be spent nuclear fuel assemblies from boiling-water and pressurized-water reactors (Figure 2-3) that DOE would ship from commercial nuclear sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (see Figure 2-3) that the Department would ship to the repository from its facilities. The 70,000 MTHM inventory would include 50 metric tons (55 tons) of surplus weapons-usable plutonium as spent mixed-oxide fuel or immobilized plutonium. Appendix A contains additional information on the inventory and characteristics of spent nuclear fuel, high-level radioactive waste, and other materials that DOE could emplace in the proposed repository. For this EIS, a connected action includes the offsite manufacturing of the containers that DOE would use for the transport and disposal of spent nuclear fuel and high-level radioactive waste.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

Figure 2-4 is an overview of components or activities associated with the Proposed Action. The implementing alternatives and scenarios analyzed in this EIS, as described in Section 2.1.1, represent the potential range of variables associated with implementing the Proposed Action that could affect environmental impacts. The Proposed Action would require surface and subsurface facilities and operations for the receipt, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste (see Section 2.1.2) and transportation of these materials to the repository (see Section 2.1.3). Section 2.1.4 summarizes the estimated cost of the Proposed Action. Chapters 4, 5, and 6 evaluate potential environmental impacts from the Proposed Action. As part of the process to develop implementing concepts, mitigation techniques have been designed into the Proposed Action through the use of best engineering and management practices, as applicable.

The Proposed Action would use two types of institutional controls — active and passive. Active institutional controls (monitored and enforced limitations on site access; inspection and maintenance of waste packages, facilities, equipment, etc.) would be used through closure. Passive institutional controls (markers, engineered barriers, etc., that are not monitored or maintained) would be put in place during closure and used to minimize inadvertent exposures to members of the public in the future.

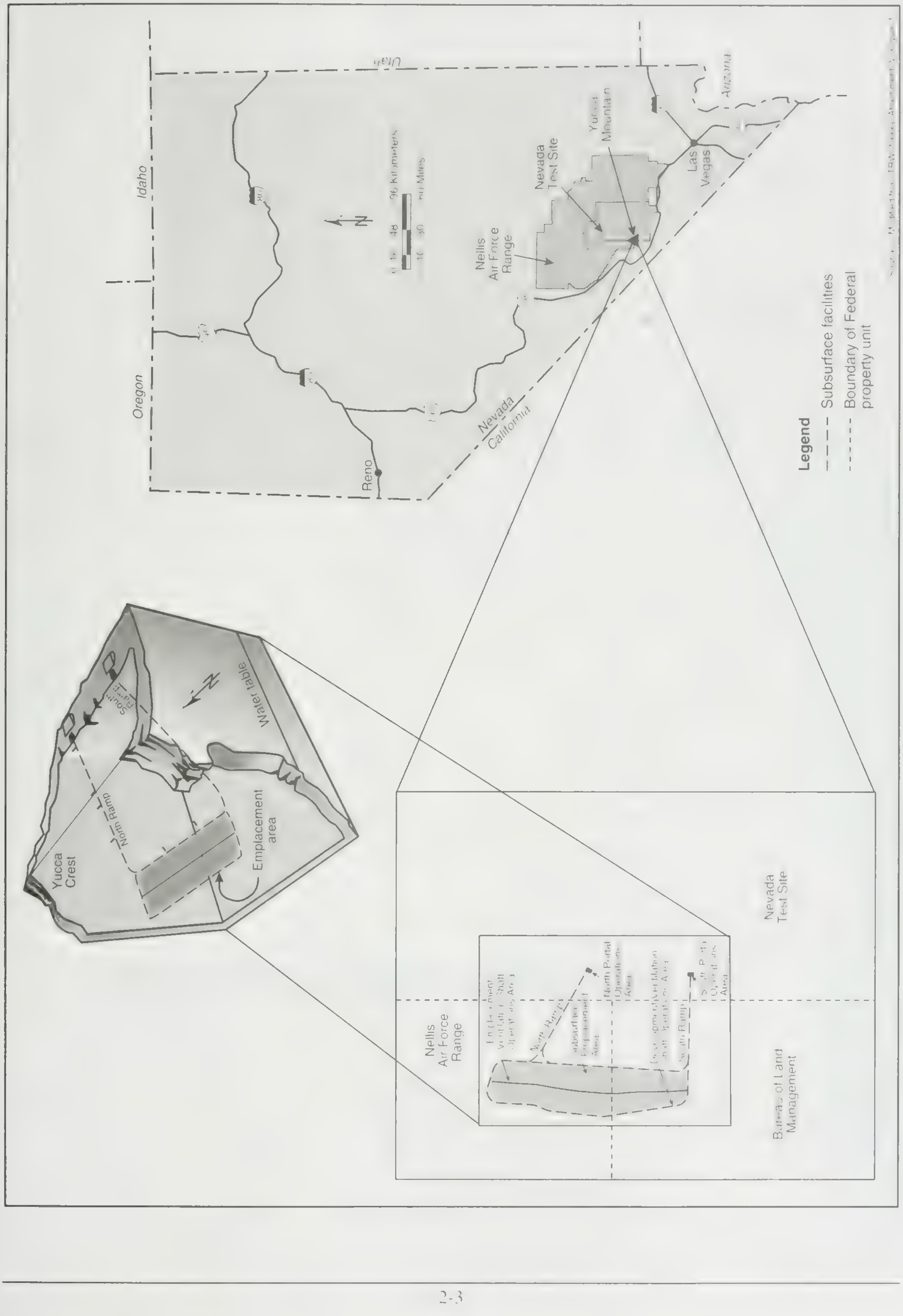


Figure 2-2. Diagram and location of the proposed repository at Yucca Mountain.

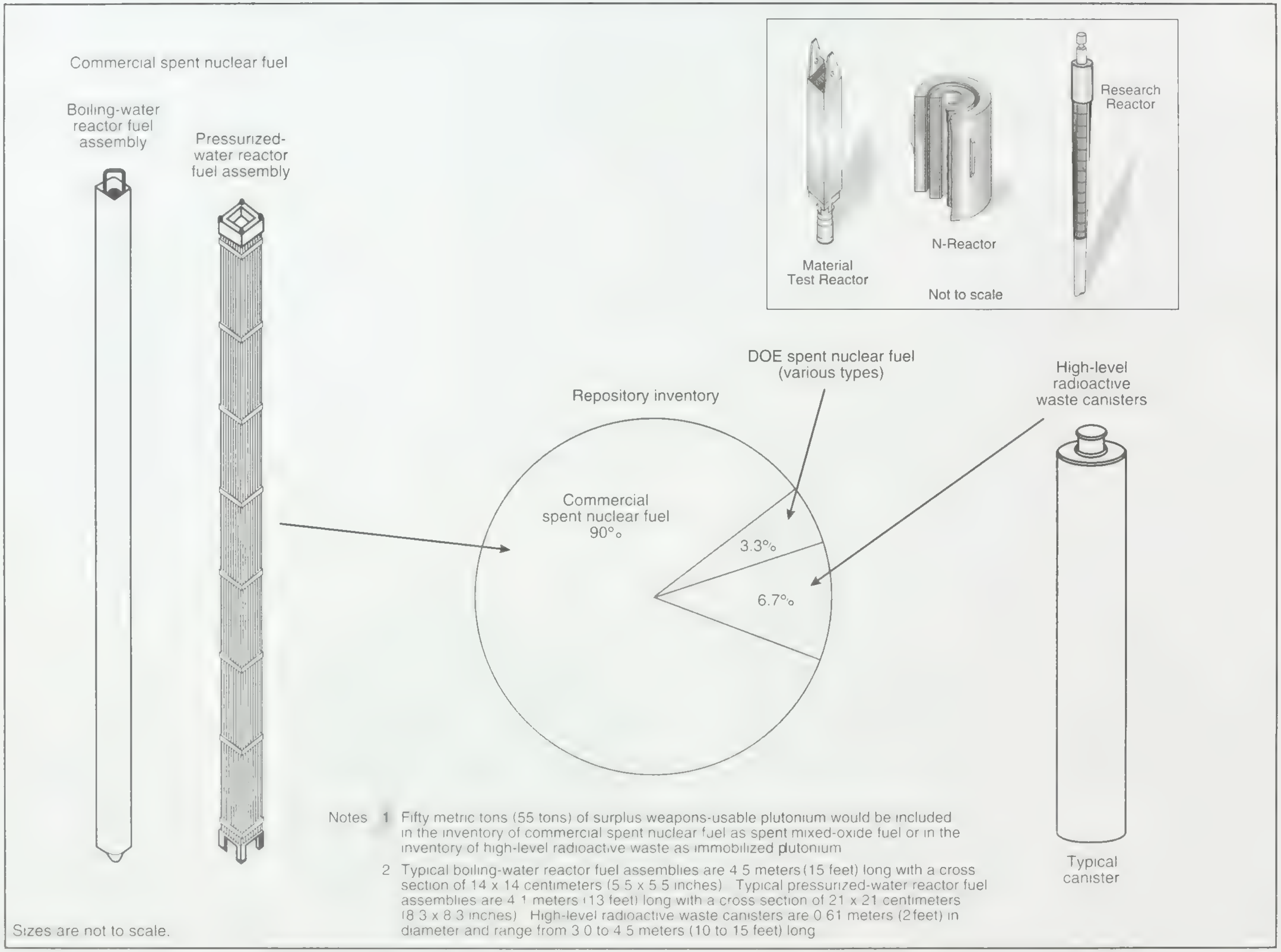


Figure 2-3. Sources of spent nuclear fuel and high-level radioactive waste proposed for disposal at the Yucca Mountain Repository.

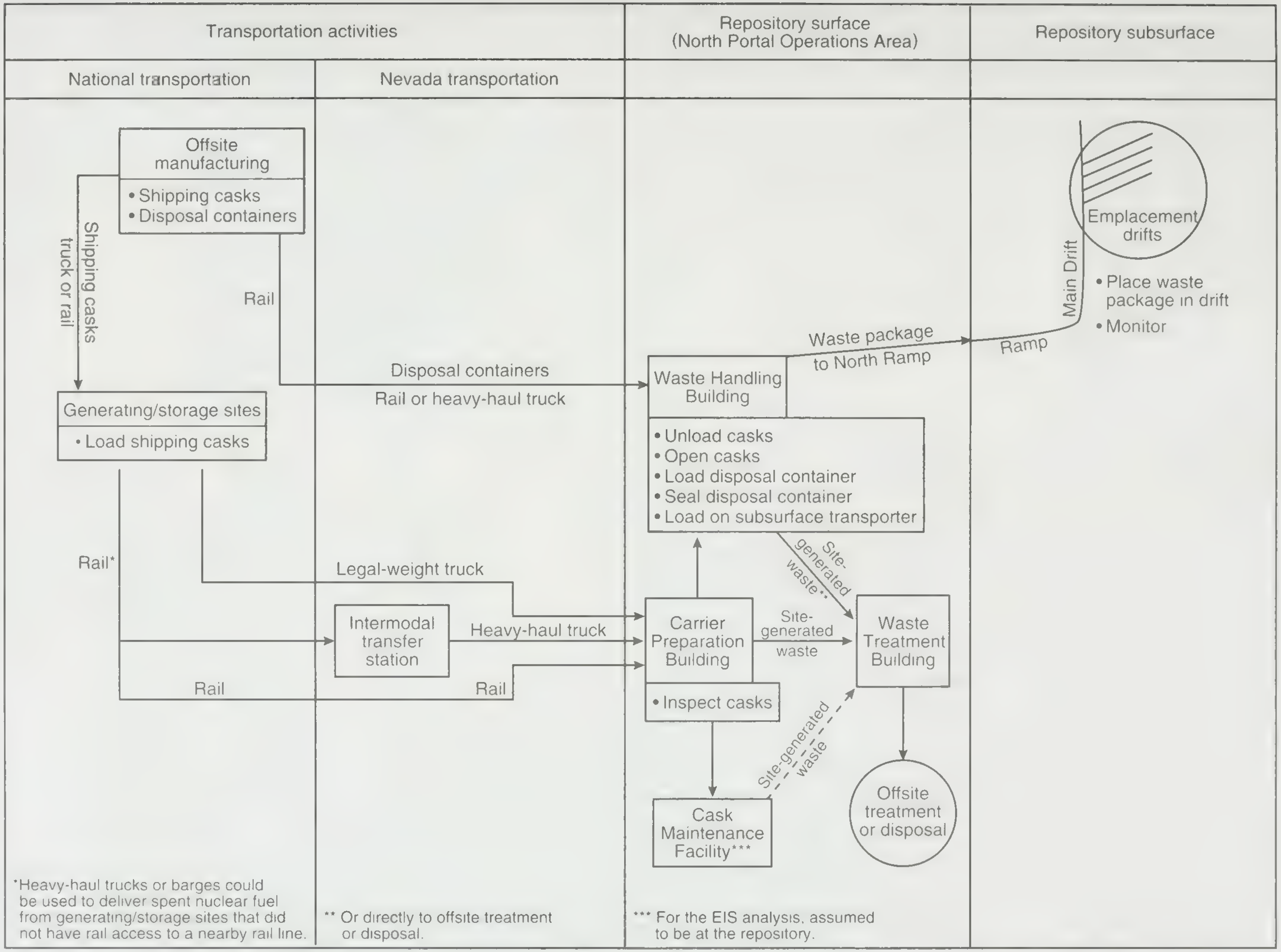


Figure 2-4. Overview flowchart of the Proposed Action.

2.1.1 OVERVIEW OF IMPLEMENTING ALTERNATIVES AND SCENARIOS

This EIS describes and evaluates the current preliminary design concept for repository surface facilities, subsurface facilities, and disposal containers (waste packages), and the current plans for the construction, operation and monitoring, and closure of the repository. DOE recognizes that plans for the repository would continue to evolve during the development of the final repository design and as a result of the U.S. Nuclear Regulatory Commission licensing review of the repository. In addition, decisions on how spent nuclear fuel and high-level radioactive waste would be shipped to the repository (for example, truck or rail) and how spent nuclear fuel would be packaged (uncanistered or in disposable or dual-purpose canisters) would be part of future transportation planning efforts.

For these reasons, DOE developed implementing alternatives and analytical scenarios to bound the environmental impacts likely to result from the Proposed Action (see Figure 2-5). The Department selected the implementing alternatives and scenarios to accommodate and maintain flexibility for potential future revisions to the design and plans for the repository. Because of uncertainties, DOE selected implementing alternatives and scenarios that incorporate conservative assumptions that tend to overstate the risks to address those uncertainties.

The following paragraphs describe the packaging scenarios, thermal load scenarios, national transportation scenarios, Nevada transportation scenarios, and implementing rail and intermodal alternatives evaluated in the EIS. In addition, these paragraphs discuss the continuing investigation of options DOE is considering for the repository design at the next major program milestones (that is, Site Recommendation and License Application).

DOE will evaluate future repository design revisions in accordance with its regulations for implementing the National Environmental Policy Act (10 CFR 1021.314) to determine if there are substantial changes in the proposal or significant new circumstances or information relevant to environmental concerns. Based on these regulations, DOE will determine whether it will conduct further National Environmental Policy Act reviews.

2.1.1.1 Packaging Scenarios

DOE operations at repository surface facilities would differ depending on how the spent nuclear fuel in shipping casks was packaged. Commercial spent nuclear fuel could be received either uncanistered or in disposable or dual-purpose canisters.

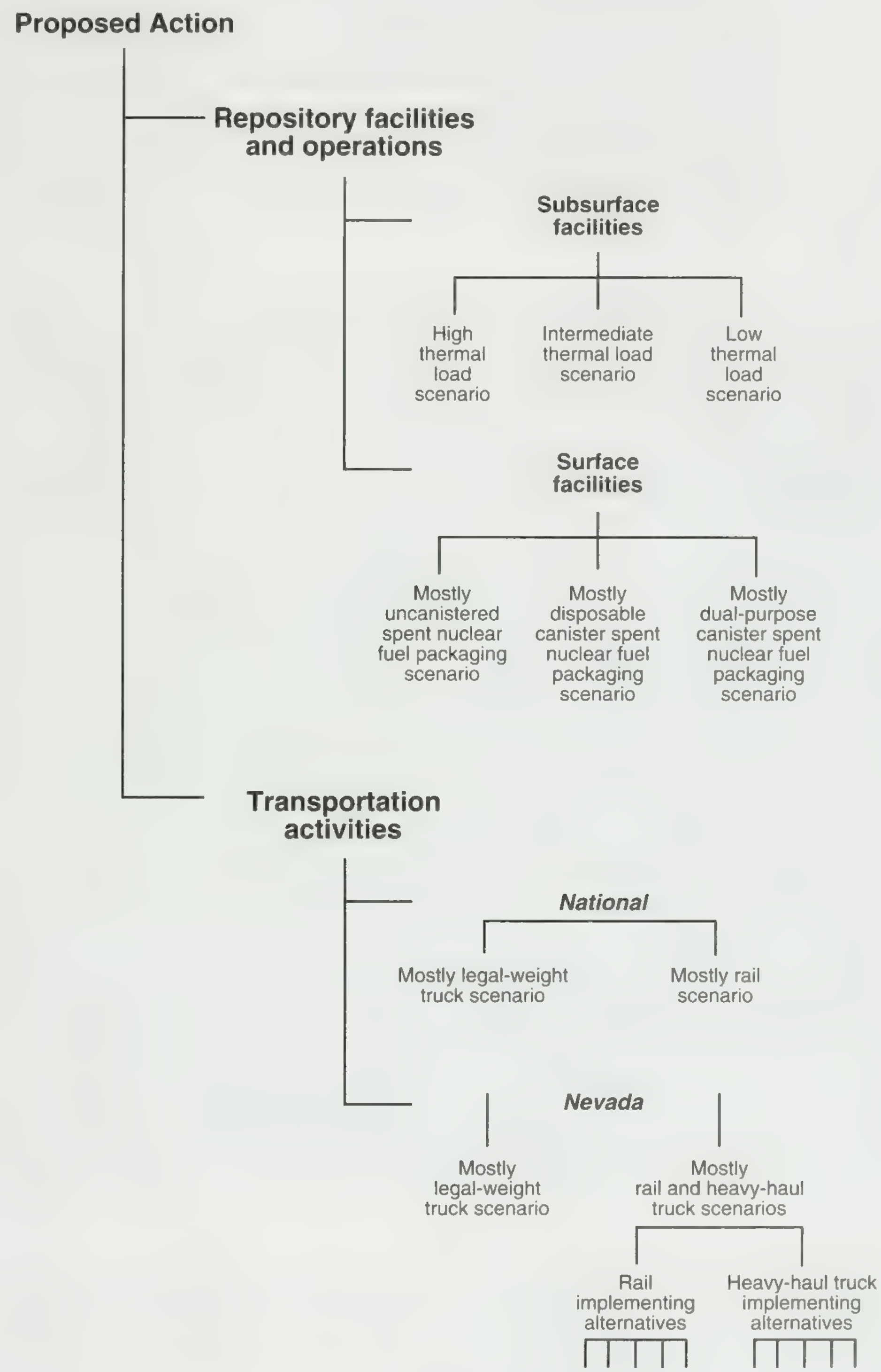
The EIS assumes that DOE spent nuclear fuel and high-level radioactive waste would be shipped to the repository in disposable canisters. In addition, it evaluates the following packaging scenarios for commercial spent nuclear fuel to cover the potential range of environmental impacts from repository surface facility construction and operation:

- A mostly uncanistered fuel scenario
- A mostly canistered fuel scenario that includes:
  - Disposable canisters
  - Dual-purpose canisters

Table 2-1 summarizes these scenarios.

DISPOSAL CONTAINERS AND WASTE PACKAGES

A *disposal container* is the vessel consisting of the barrier materials and internal components in which the spent nuclear fuel and high-level radioactive waste would be placed. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.



Note: Thermal load scenarios also affect surface facilities.

Figure 2-5. Analytical scenarios and implementing alternatives associated with the Proposed Action.

Table 2-1. Packaging scenarios (percentage based on number of shipments).

Material[a]	Mostly uncanistered fuel	Mostly canistered fuel: Disposable canister	Mostly canistered fuel: Dual-purpose canister
Commercial SNF	100% uncanistered fuel	About 80% disposable canisters; about 20% uncanistered fuel	About 80% dual-purpose canisters; about 20% uncanistered fuel
HLW	100% disposable canisters	100% disposable canisters	100% disposable canisters
DOE SNF	100% disposable canisters	100% disposable canisters	100% disposable canisters

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A thick-walled vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Canister: A thin-walled metal vessel used to hold spent nuclear fuel assemblies or solidified high-level radioactive waste.

Dual-purpose canister: A canister suitable for storing (in a storage facility) and shipping (in a shipping cask) spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A canister for spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container.

Uncanistered spent nuclear fuel: Fuel placed directly into storage canisters or shipping casks without first being placed in a canister. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

2.1.1.2 Thermal Load Scenarios

The heat generated by spent nuclear fuel and high-level radioactive waste (the thermal load) could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier systems to isolate the emplaced waste from the human environment). Different thermal loads would have a direct effect on internal and external waste package temperatures, thereby potentially affecting the corrosion rate and integrity of the waste package. The heat generated by the waste packages would also affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn would influence the flow of groundwater and the transport of radionuclides from the engineered and natural barrier systems to the environment. The thermal load would depend on factors related to the

design of the repository including, but not limited to, the age of the spent nuclear fuel at the time of emplacement, the spacing of the emplacement drifts and the waste packages in them, the repository ventilation, and the decision on whether to backfill the emplacement drifts.

DOE evaluated three thermal load scenarios. These scenarios include a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load – 85 MTHM per acre), a relatively low emplacement density (low thermal load 25 MTHM per acre), and an emplacement density between the high and low thermal loads (intermediate thermal load – 60 MTHM per acre). The additional spacing required for the lower thermal loads would increase the subsurface area and the amount of excavation. In addition, the different thermal loads would affect the area requirements for the excavated rock pile on the surface.

2.1.1.3 National Transportation Scenarios

The national transportation scenarios evaluated in this EIS encompass the transportation options or modes (legal-weight truck and rail) that are practical for DOE to use to ship spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. DOE would use both legal-weight truck and rail transportation, and would determine the number of shipments by either mode as part of future transportation planning efforts. Therefore, the EIS evaluates two national transportation scenarios (mostly legal-weight truck and mostly rail) that cover the possible range of transportation impacts to human health and the environment.

TERMS ASSOCIATED WITH TRANSPORTATION

Legal-weight trucks have a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be in compliance with Federal and state regulations.

An **intermodal transfer station** is a facility for transferring freight from one transportation mode to another (for example, from railcar to truck). In this EIS, intermodal transfer station refers to a facility DOE would use to transfer rail shipping casks containing spent nuclear fuel or high-level radioactive waste from railcars to heavy-haul trucks, and to transfer empty rail shipping casks from heavy-haul trucks to railcars.

Heavy-haul trucks are overweight, overdimension vehicles that must have permits from state highway authorities to use public highways. In this EIS, heavy-haul trucks refers to vehicles DOE would use on public highways to move spent nuclear fuel or high-level radioactive waste shipping casks designed for a railcar.

2.1.1.4 Nevada Transportation Scenarios and Rail and Intermodal Implementing Alternatives

The transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository would affect all the states through which the shipments would travel, including Nevada. However, to highlight the impacts that could occur in Nevada, DOE has chosen to discuss them separately. DOE is looking at three transportation scenarios for Nevada. These scenarios include legal-weight truck and rail, which are the same as the national scenarios but highlight the Nevada portion of the transportation, and heavy-haul truck. The heavy-haul truck scenario includes the construction of an intermodal transfer station with associated highway improvements for heavy-haul trucks in the State. DOE has identified five potential rail corridors leading to Yucca Mountain and three potential intermodal transfer station locations with five

associated potential highway routes for heavy-haul trucks. Section 2.1.3.3 describes these implementing alternatives.

2.1.1.5 Continuing Investigation of Design Options

As noted, this EIS describes and evaluates the current preliminary design concept for the repository and current plans for repository construction, operation and monitoring, and closure (see Section 2.1.2). DOE continues to investigate design options for possible incorporation in the final repository design; Appendix E identifies design features and alternative design concepts that DOE is considering for the final design (for example, smaller waste packages, a waste package design using two corrosion-resistant materials, and a long-term ventilated repository). The criteria for selecting these design options are related to improving or reducing uncertainties in repository performance (the potential to provide containment and isolation of radionuclides) and operation (for example, worker and operational safety, ease of operation).

DOE has assessed each of the design options still being considered for the expected change it would have on short- and long-term environmental impacts and has compared these impacts to the potential impacts determined for the packaging, thermal load, and transportation scenarios evaluated in the EIS. This assessment, which is described in Appendix E, found that the changes in environmental impacts for the design options would be relatively minor in relation to the potential impacts evaluated in this EIS. Therefore, DOE has concluded that the analytical scenarios and implementing alternatives evaluated in this EIS provide a representative range of potential environmental impacts the Proposed Action could cause. Chapter 9 discusses mitigation from design options that could be beneficial in reducing impacts associated with repository performance or operation.

2.1.2 REPOSITORY FACILITIES AND OPERATIONS

This section describes proposed repository surface and subsurface facilities and operations (Sections 2.1.2.1 and 2.1.2.2), repository closure (Section 2.1.2.3), and the performance confirmation program (Section 2.1.2.4). The description is based on TRW (1999a, all), TRW (1999b, all), and TRW (1999c, all), unless otherwise noted. The following paragraphs contain an overview of the repository facilities and operations and the sequence of planned repository construction, operation and monitoring, and closure. DOE would design the repository based on the extensive information collected during the Yucca Mountain site characterization activities. These activities are summarized in semiannual site characterization reports. [See the semiannual Site Characterization Progress Reports that the Department prepares in accordance with Section 113(b)(3) of the NWPA (for example, DOE 1991a, all).] The facilities used for site characterization activities at Yucca Mountain would be incorporated in the repository design to the extent practicable. (See Chapter 3, Section 3.1, for additional information on existing facilities at Yucca Mountain developed during site characterization activities.)

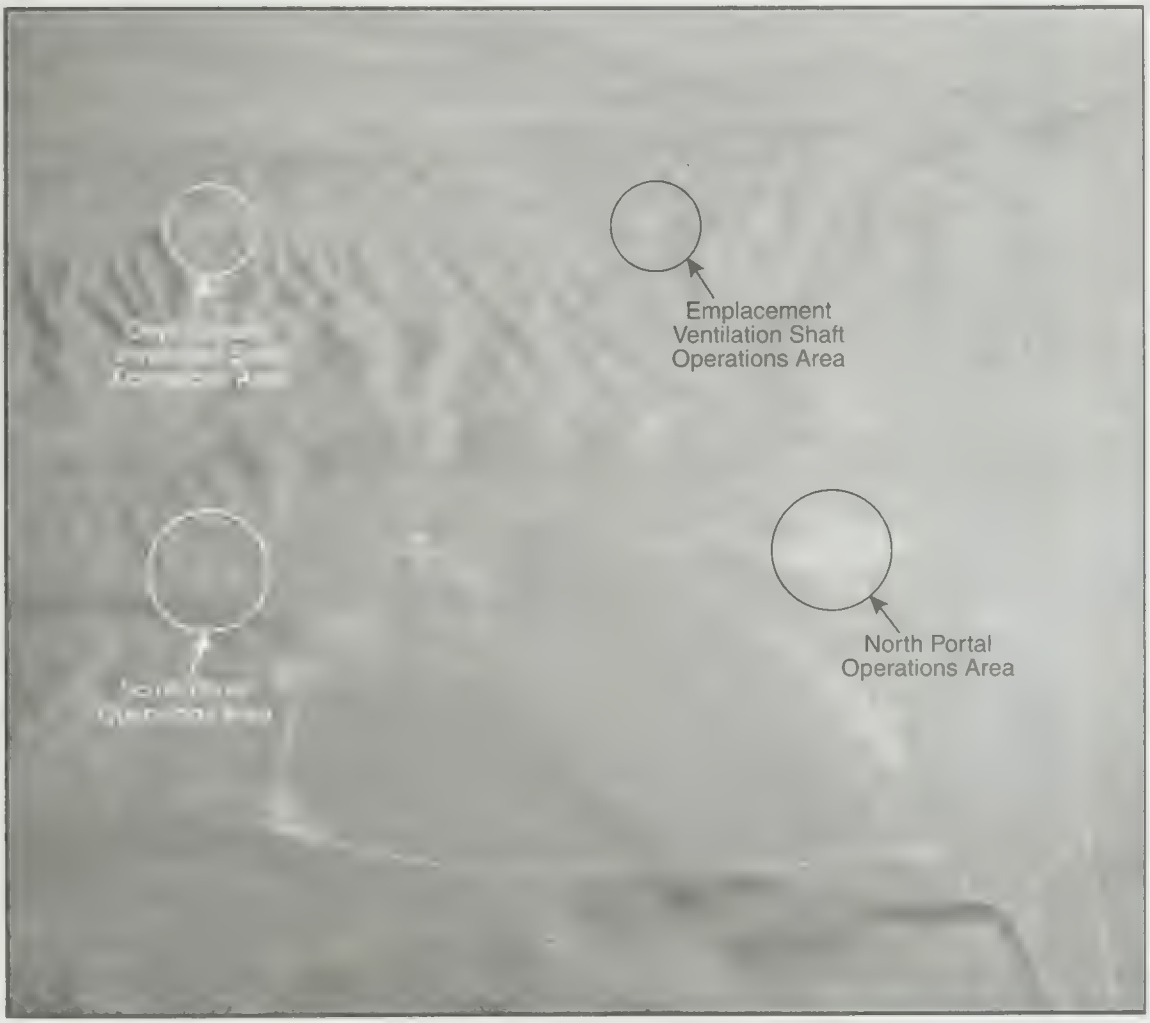
DOE would construct surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement. In addition, surface facilities would support the construction of subsurface facilities. These facilities include the following primary surface operations areas:

- North Portal Operations Area Receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement
- South Portal Operations Area Support the construction of subsurface facilities

- Emplacement Ventilation Shaft Operations Area Exhaust air from the subsurface facilities where waste packages would be emplaced (emplacement side)

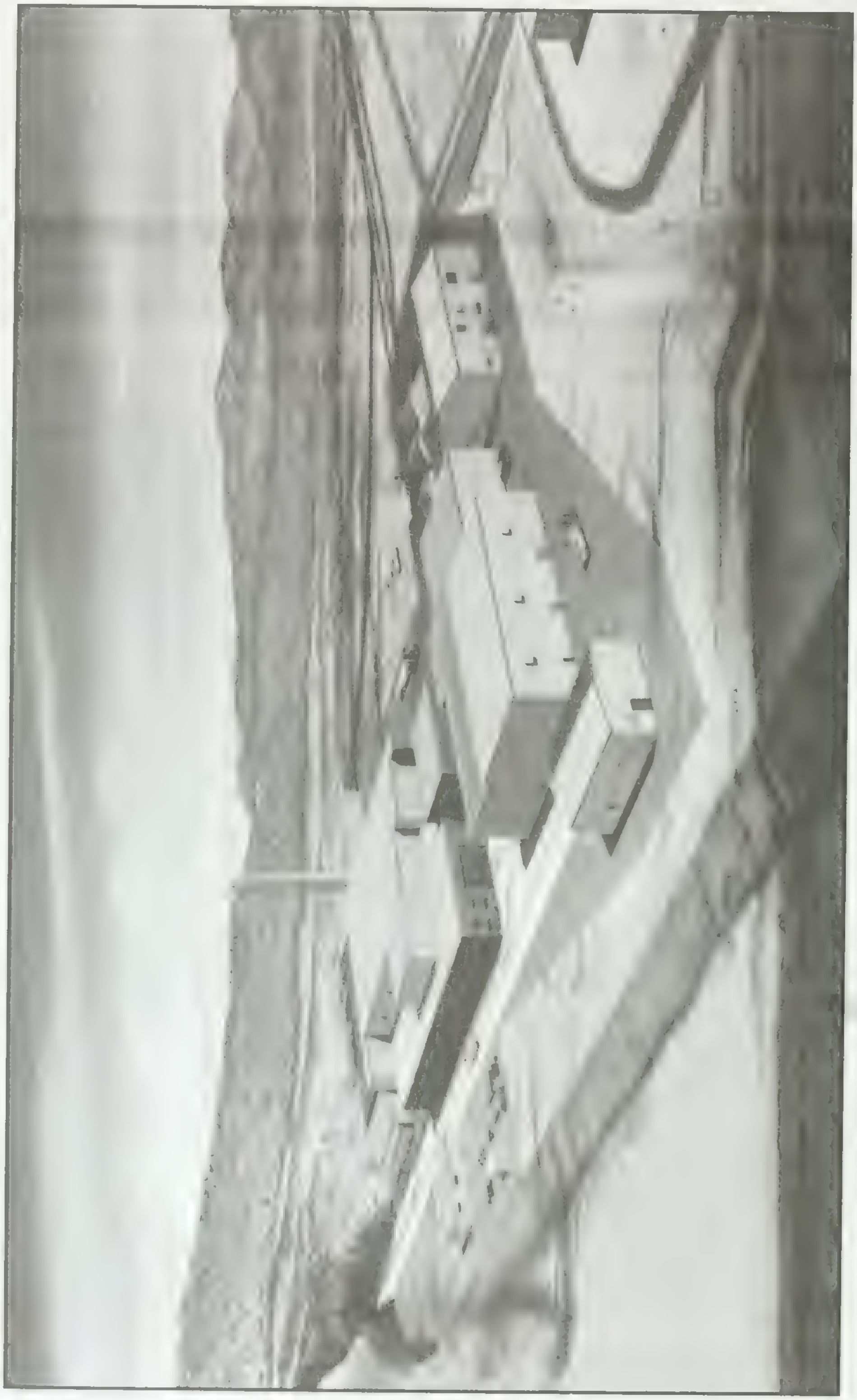
- Development Ventilation Shaft Operations Area Supply air to subsurface facilities where construction activities would occur (development side)

Figure 2-6 is an aerial photograph of the Yucca Mountain site showing the locations of these surface facilities. Figure 2-7 is an illustration of the repository surface facilities at the North Portal Operations Area. The spent nuclear fuel and high-level radioactive waste would be handled remotely with workers shielded from exposure to radiation using design and operations practices in use at licensed nuclear facilities to the maximum extent practicable. The repository operations areas and supporting areas, utilities, roads, etc., would require the active use of about 3.5 square kilometers (870 acres) of land. Of this total area, about 1.5 square kilometers (370 acres) have been disturbed by previous activities.



Note: The North and South Portal Operations Areas are approximately 2.7 kilometers (1.7 miles) apart.

Figure 2-6. Surface facilities at the proposed Yucca Mountain Repository.



Source: DOE (1998a Overview page 13)

Figure 2-7. Artist's conception of proposed repository surface facilities at the North Portal Operations Area.

Figure 2-8 shows the subsurface layout of the repository, which would consist of tunnels (called *drifts*) and vertical ventilation shafts that DOE would excavate in the mountain. Along with the main drifts, gently sloping ramps from the surface to the subsurface facilities would move workers, equipment, and waste packages. Waste packages of spent nuclear fuel and high-level radioactive waste would be placed in the emplacement drifts. The ventilation systems would move air for workers and would cool the repository.

Figure 2-9 shows the expected timing for construction, operation and monitoring, and closure of the proposed repository at Yucca Mountain. If a recommendation was made to proceed with the development of the repository, DOE would continue performance confirmation activities to support a License Application to the Nuclear Regulatory Commission. Preconstruction performance confirmation activities at and in the vicinity of the Yucca Mountain site would be similar to those performed during site characterization. These activities could require surface excavations, subsurface excavations and borings, and in-place testing of rock characteristics.

The construction of repository facilities for the handling of spent nuclear fuel and high-level radioactive waste could begin only after the receipt of construction authorization from the Nuclear Regulatory Commission. For this EIS, DOE assumed that construction would begin in 2005. The repository surface facilities, the main drifts, ventilation system, and initial emplacement drifts would be built in approximately 5 years, from 2005 to 2010.

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of these materials would begin in 2010 and that emplacement would occur over a 24-year period ending in 2033, based on the emplacement of 70,000 MTHM at approximately 3,000 MTHM per year.

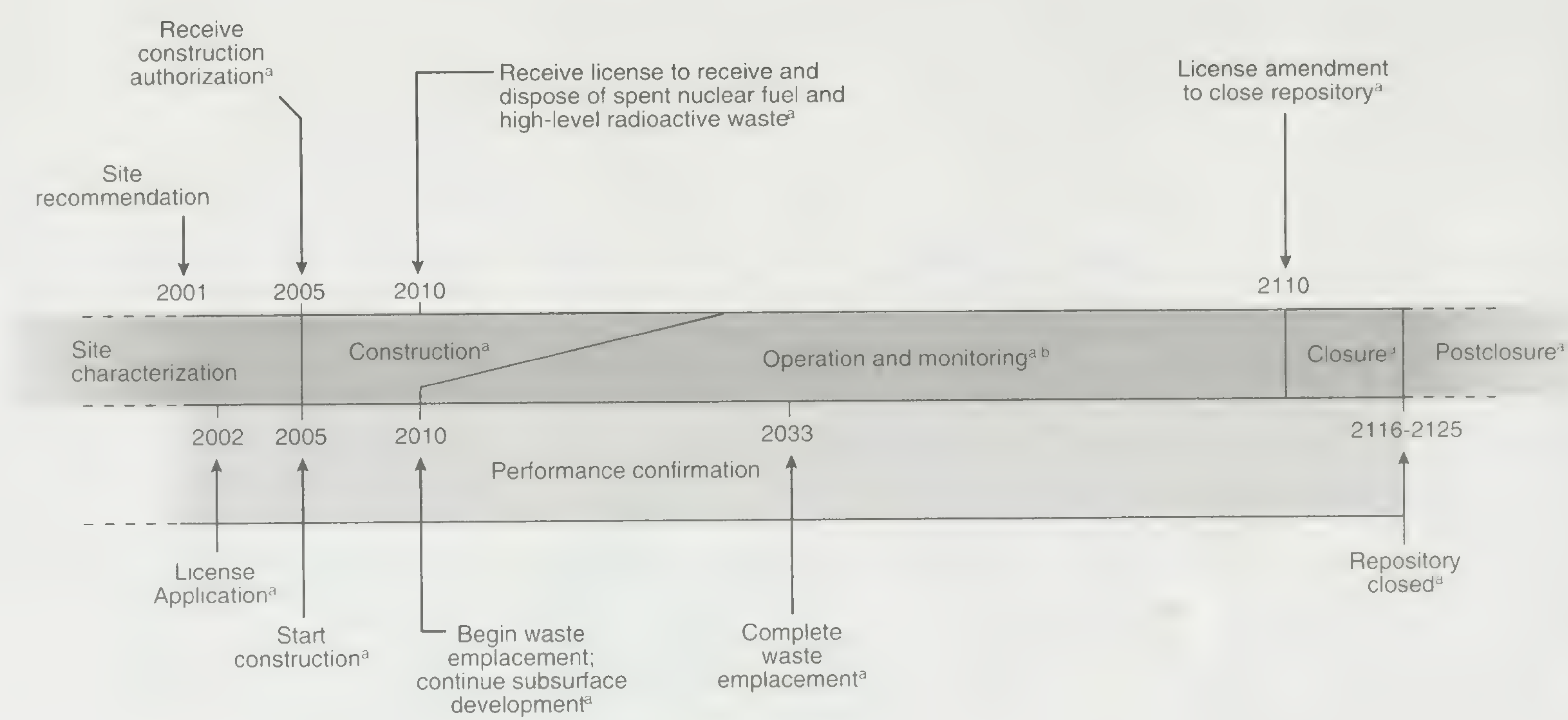
The construction of emplacement drifts would continue during emplacement and would end in about 2032. The repository design would enable simultaneous construction and emplacement operations, but it would physically separate activities on the construction or development side from activities on the emplacement side.

Monitoring and maintenance activities would start with the first emplacement of waste packages and would continue through repository closure. After the completion of emplacement, DOE would maintain those repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable continued monitoring and inspection of the emplaced waste packages, continued investigations in support of predictions of long-term repository performance, and the retrieval of waste packages if necessary. Immediately after the completion of emplacement, DOE would decontaminate and close the facilities that handled nuclear materials on the surface to eliminate a potential radioactive material hazard. However, DOE would maintain an area of the Waste Handling Building for the possible recovery and testing of waste packages as a quality assurance contingency in the performance confirmation program (see Section 2.1.2.4). Future generations would decide whether to continue to maintain the repository in an open monitored condition or to close it. To ensure flexibility to future decisionmakers, DOE is designing the repository with the capability for closure as early as 50 years or as late as 300 years after the start of emplacement. This EIS assumes that closure would begin 100 years after the start (76 years after the completion) of emplacement, but assesses impacts (in Chapter 4) for closure beginning 50 and 300 years after the start of emplacement.

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. The period to accomplish closure would range from about 6 years for the high thermal load scenario to about 15 years for the low thermal load scenario. The closure of the repository facilities

Source: Modified from DOE (1998a, Overview, page 9).

Figure 2-8. Artist's conception of proposed repository subsurface layout.



a. If Yucca Mountain is approved.
b. The EIS analysis assumed that waste emplacement would occur over a 24-year period ending in 2033.

Source: Modified from TRW 1999b, Figure 1.5.1, page 1.3

Figure 2-9. Expected monitored geologic repository milestones.

would include closing the subsurface facilities, decontamination and decommissioning the surface facilities, reclaiming the site, and establishing long-term institutional barriers, including land records and warning systems to limit or prevent intentional or unintentional activity in and around the closed repository (see Section 2.1.2.3).

The performance confirmation program would continue some site characterization activities through repository closure, including various types of tests, experiments, and analytical procedures. DOE would conduct performance confirmation activities to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objectives for the period after permanent closure (see Section 2.1.2.4).

2.1.2.1 Repository Surface Facilities and Operations

Surface facilities at the repository site would be used to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for subsurface emplacement. Surface facilities would also support the construction of the subsurface facilities. DOE would upgrade some facilities built for site characterization, but most surface facilities would be new. Most facilities would be in four areas the North Portal Operations Area, the South Portal Operations Area, the Emplacement Ventilation Shaft Operations Area(s), and the Development Ventilation Shaft Operations Area(s)—as shown on Figure 2-10. Facilities to support waste emplacement would be concentrated near the North Portal, and facilities to support subsurface facility development would be concentrated near the South Portal.

2.1.2.1.1 *North Portal Operations Area*

This area, shown in Figure 2-11, would be the largest of the primary operations areas, covering about 0.6 square kilometer (150 acres) at the North Portal. It would include two areas: a Restricted Area for receipt of spent nuclear fuel and high-level radioactive waste handling and packaging for emplacement, and a Balance of Plant Area for support services (administration, training, emergency, and general maintenance). The Restricted Area (called the *Radiologically Controlled Area* in other DOE documents) would be enclosed by a fence and monitored to ensure adequate safeguards and security for radioactive materials. The two principal facilities in the Restricted Area would be the Carrier Preparation Building and the Waste Handling Building. Other support facilities planned for the North Portal Operations Area include basic facilities for personnel support, warehousing, security, and transportation (motor pool).

When a legal-weight truck or railcar hauling a cask containing spent nuclear fuel or high-level radioactive waste arrived at the repository site, it would move through the security check into the Restricted Area parking area or to the Carrier Preparation Building. Rail casks arriving on heavy-haul trucks might be transferred to a railcar outside the Restricted Area before entering it. Operations in the Carrier Preparation Building would include performing inspections of the vehicle and cask, removing barriers from the vehicle that protected personnel during shipment, and removing impact limiters from the cask. The vehicle would then move to the Waste Handling Building for unloading or to a storage yard until space became available for unloading. In the Waste Handling Building shipping casks would be removed from the vehicle and placed on carts (see Figure 2-12). The carts would move through the Waste Handling Building airlock to cask preparation areas, where the casks would be checked for contamination and the interior gases sampled. The casks would then be vented and cooled, and the cask lids would be unbolted.

After cask preparation operations, receipt and packaging operations would begin; the nature of these operations would depend on how the spent nuclear fuel in the shipping cask was packaged. The following paragraphs describe the different receipt and packaging operations for different types of packages.

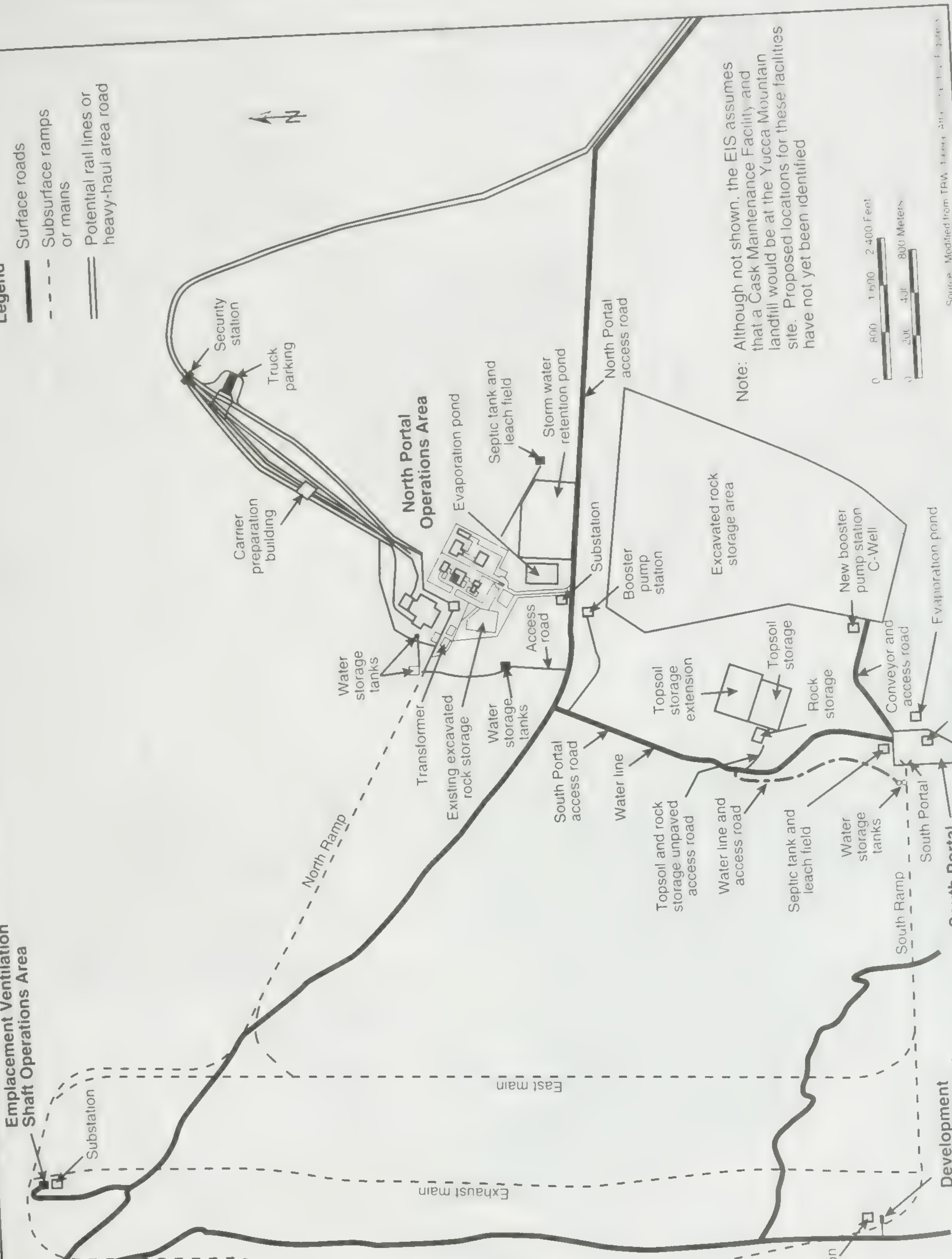


Figure 2-10. Repository surface facilities site plan.

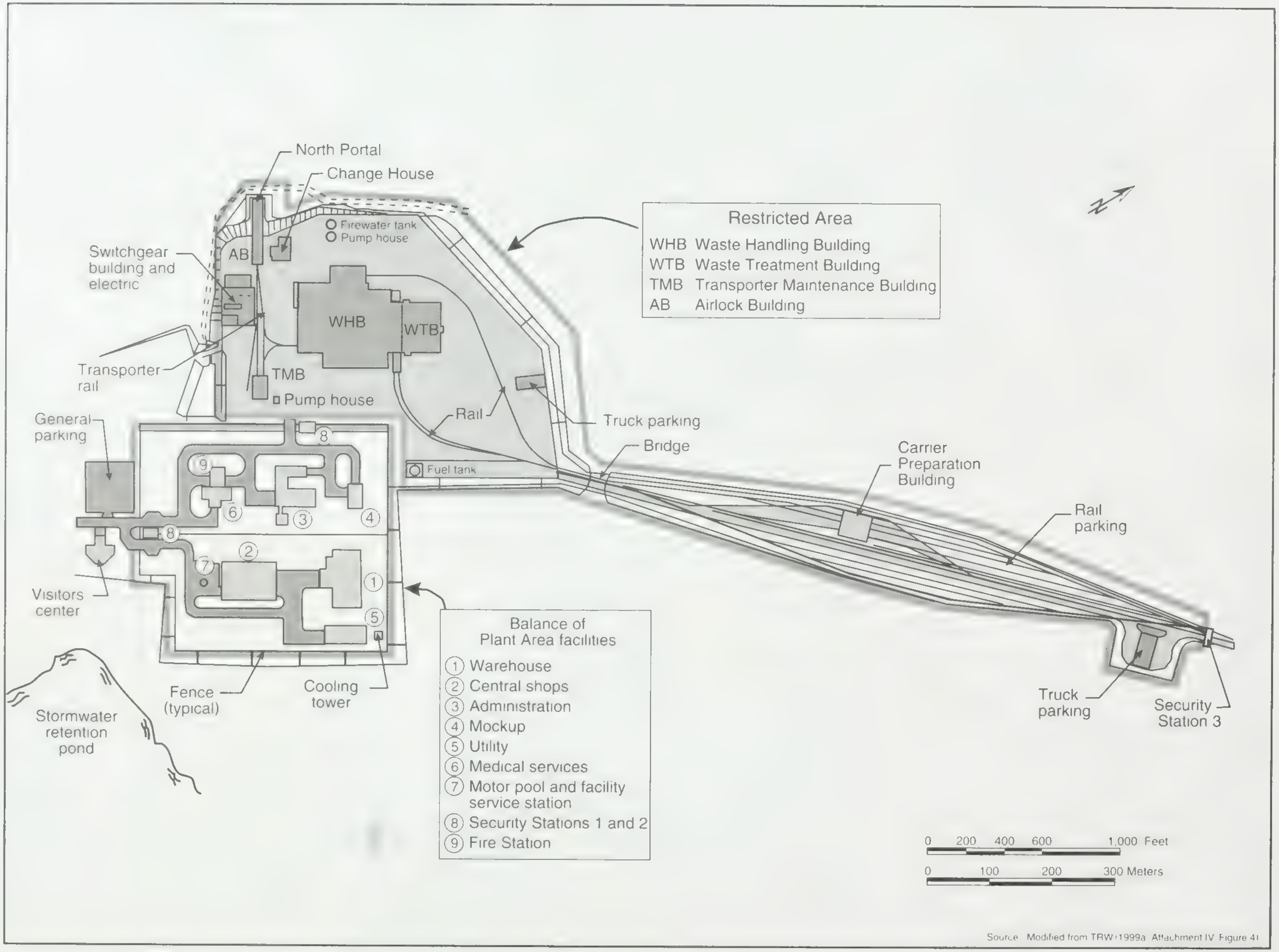


Figure 2-11. North Portal Operations Area site plan.

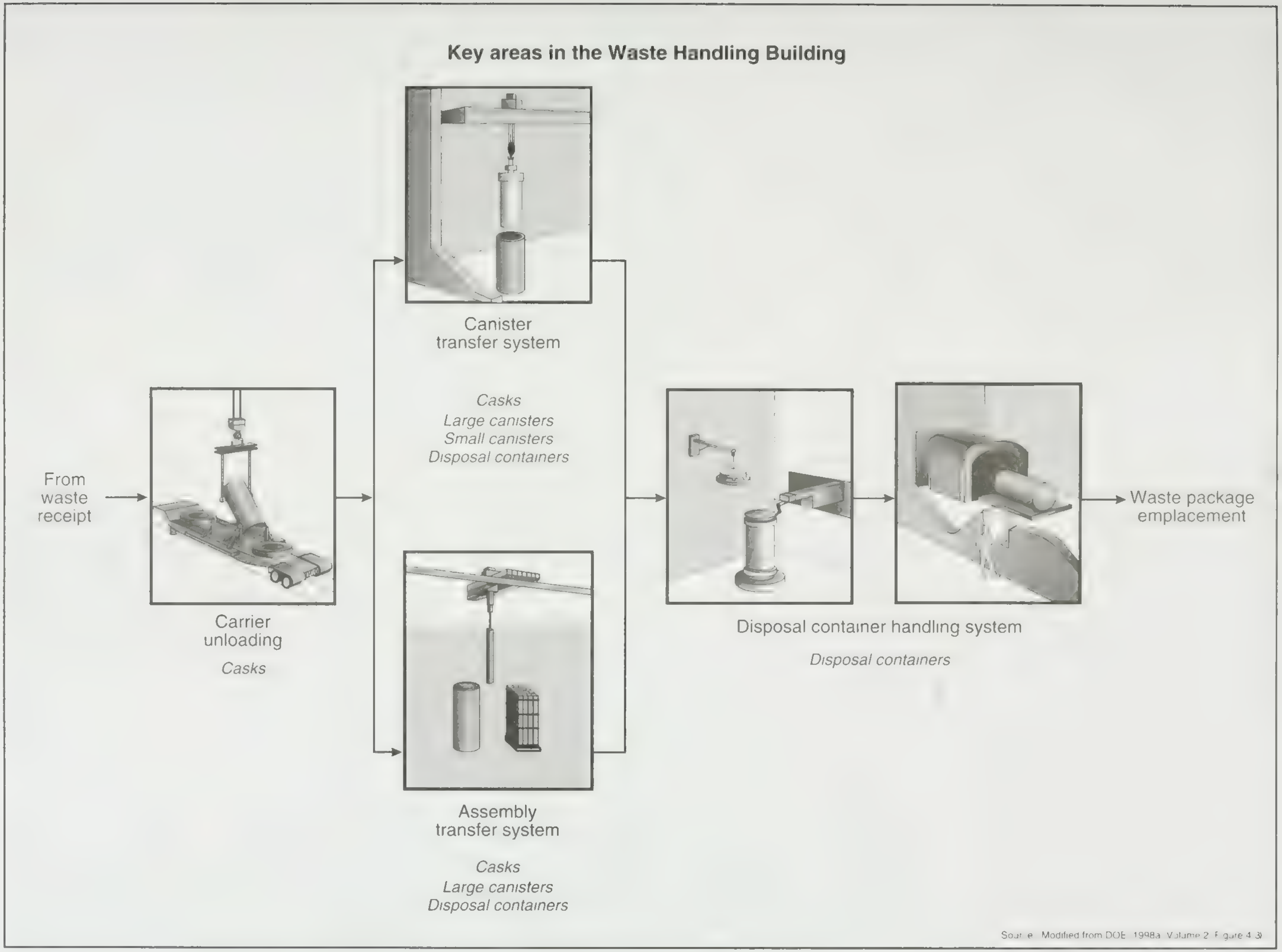


Figure 2-12. Key components of the waste handling operations.

Uncanistered spent nuclear fuel in a cask would be placed in a water transfer pool in the Waste Handling Building. The cask lid would be removed and each fuel assembly would be removed and placed in a transfer basket. When the transfer basket was loaded, it would be *staged* or moved from the pool to an assembly transfer cell and dried. The dried assemblies would be loaded in a disposal container, which would be decontaminated, and either transferred directly to a welding area or stored temporarily until a welding area was available. Welding operations would include installing and welding the inner and outer lids of the disposal container. The disposal container would be filled with an inert gas such as helium after the inner lid was welded. Each welding operation would be followed by nondestructive weld examination and certification. After weld certification, the loaded disposal container is called a *waste package* (see Section 2.1.2.2). Each waste package would be decontaminated and loaded in a shielded waste package transporter for transfer to the repository or held in the Waste Handling Building until a transporter became available.

Shipping casks containing spent nuclear fuel or high-level radioactive waste in disposable canisters would be moved directly to a dry canister transfer handling area. The shipping cask lid would be removed and the disposable canisters would be staged, or transferred directly into a disposal container. The disposal container sealing and welding process would be similar to that described for uncanistered spent nuclear fuel.

Shipping casks containing spent nuclear fuel assemblies in dual-purpose canisters would be placed in a water transfer pool. The shipping cask lid would be removed, the canister inside would be removed and opened, and the assemblies would be unloaded to a transfer basket. Once the assemblies were in the basket, the process would be the same as that described for uncanistered fuel.

DOE would decontaminate empty canisters, shipping casks, and related components as required in the Waste Handling Building. After decontamination, the empty canisters and shipping casks would be loaded on truck or rail carriers, sent to the Carrier Preparation Building for processing, and shipped off the site.

Waste generated at the repository from the decontamination of canisters and shipping casks and from other repository housekeeping activities would be collected, processed, packaged, and staged in the Waste Treatment Building before being shipped off the site for disposal at permitted facilities. Waste minimization and pollution prevention measures would reduce the amount of site-generated waste requiring such management. For example, decontamination water could be treated and recycled to the extent practicable. Site-generated wastes would include low-level radioactive waste, hazardous waste, and industrial solid waste. Operations would not be likely, but that could occur, could produce small amounts of mixed wastes (wastes containing both radioactive and hazardous materials). The repository design would include provisions for collecting and storing mixed waste for offsite disposal.

The ventilation systems for the Waste Handling Building and the Waste Treatment Building would provide confinement of radioactive contamination by using pressure differentials to ensure that the air would flow from areas free of contamination to areas potentially contaminated to areas that are normally contaminated. The monitored exhaust air from both buildings would pass through high-efficiency particulate air filters before being released through a single exhaust stack.

2.1.2.1.2 *South Portal Operations Area*

The South Portal Operations Area would cover about 0.15 square kilometer (37 acres) immediately adjacent to the South Portal of the subsurface facility. The structures and equipment in this area, which would support the development of subsurface facilities, would include a concrete plant for fabricating and curing precast components and supplying concrete for in-place casting, and basic facilities for personnel

support, maintenance, warehousing, material staging, security, and transportation. From this area, overland conveyors would transport excavated rock from the repository to the excavated rock pile.

2.1.2.1.3 *Emplacement Ventilation Shaft Operations Areas*

DOE would develop these areas where ventilation shafts from the emplacement side of the subsurface reached the surface. The number of shafts required to ventilate the subsurface would depend on the thermal load scenario for the repository. A repository design with a high or intermediate thermal load would require a single ventilation shaft with a corresponding surface operations area for the emplacement side. A design with a low thermal load would require three emplacement ventilation shafts with corresponding surface operations areas because of the increased area to be ventilated. Two of these operations areas would contain fans to pull air from the emplacement area; the other would not contain fans but would supply air to the emplacement area.

An Emplacement Ventilation Shaft Operations Area would cover about 12,000 square meters (3 acres) and would normally be unstaffed. An emplacement side ventilation system would contain two fans, each driven by a 2,000-horsepower electric motor with a capacity of about 17,000 cubic meters (600,000 cubic feet) per minute. One fan would be in continuous operation and the other would be on standby. Section 2.1.2.2 contains a description of the subsurface ventilation design.

2.1.2.1.4 *Development Ventilation Shaft Operations Areas*

Development ventilation shafts would supply air to the development side of the repository. A repository design with a high or intermediate thermal load would require a single development ventilation shaft with a corresponding surface operations area. A design with a low thermal load would require two development ventilation shafts with corresponding surface operations areas because of the increased area to be ventilated. Each Development Ventilation Shaft Operations Area would be similar in size to the Emplacement Ventilation Shaft Operations Areas, and would contain two fans, each with a capacity of about 17,000 cubic meters (600,000 cubic feet) per minute and driven by a 2,000-horsepower electric motor. One fan would be in continuous operation, forcing air into the repository, and the other fan would be on standby. Section 2.1.2.2 contains a description of the subsurface ventilation design.

2.1.2.1.5 *Support Equipment and Utilities*

Repository support equipment and utilities would be on the surface in the general vicinity of the North and South Portal Operations Areas (see Figure 2-10). The storage area for excavated rock would be the largest support area. For the high or intermediate thermal load scenario, the excavated rock storage area would be between the North and South Portals, as shown in Figure 2-10, and would require about 1.0 and 1.2 square kilometers (250 and 300 acres), respectively. For the low thermal load scenario, the excavated rock storage area would be about 5 kilometers (3 miles) east of the South Portal Operations Area, as shown on Figure 2-13. Because the excavated rock pile would be higher at this location, the area required would be about 1.1 square kilometers (270 acres).

The repository site would have two evaporation ponds for industrial wastewater, one at the North Portal and one at the South Portal. Sources of industrial wastewater would include water used for dust suppression during construction, water used for cooling tower operations at the North Portal, and water used for concrete mixing and for form cleanup at the South Portal. Heavy plastic sheets would line both ponds to prevent water migration into the soil. The North Portal pond would cover about 24,000 square meters (6 acres). The evaporation pond at the South Portal would be about 2,300 square meters (0.6 acre). The North Portal area would also include an approximately 130,000-square-meter (32-acre) stormwater retention pond to control stormwater runoff from the North Portal Operations Area.

Figure 2-13. Location of excavated rock storage area for low thermal load scenario.

DOE would develop an appropriately sized landfill [approximately 0.036 square kilometer (9 acres)] at the repository site for nonhazardous and nonradiological construction and sanitary solid waste and for similar waste generated during the operation and monitoring and closure phases. The South Portal Operations Area would have a septic tank and leach field for the disposal of sanitary sewage. The North Portal Operations Area has an existing septic system that would be adequate for use during repository operations.

At present, electric power is obtained from the Nevada Test Site power distribution system. For the repository, electric power would be distributed throughout the surface and subsurface areas and to remote areas such as the Ventilation Shaft Operations Areas, construction areas, environmental monitoring stations, transportation lighting and safety systems, and water wells. To accommodate the expected demand for the repository, DOE would upgrade existing electrical transmission and distribution systems. Backup equipment and uninterruptable electric power would be provided to ensure personnel safety and operations requiring electric power continuity. Diesel generators and associated switchgear would provide the backup power capability.

DOE would use existing wells about 5.6 kilometers (3.5 miles) southeast of the North Portal Operations Area to supply water for repository activities. These wells have supplied water for site characterization activities at Yucca Mountain. Water would be pumped to a booster pump station and then to potable and nonpotable water systems that would distribute the water to the Restricted and Balance of Plant Areas and to the subsurface.

Fuel supply systems would include fuel oil for a central heating (hot water) plant, which would consist of a 950,000-liter (250,000-gallon) main tank and a 57,000-liter (15,000-gallon) day tank. In addition, there would be fuel supply systems for generating steam to cure precast concrete, for fire water system tank heaters, for diesel-powered standby generators and air compressors, and for backup fire pumps. Diesel fuel and gasoline would also be provided to fuel vehicles during the construction, operation and monitoring, and closure of the repository.

2.1.2.2 Repository Subsurface Facilities and Operations (Including Waste Packages)

DOE would construct the subsurface facilities of the repository and emplace the waste packages above the water table in a mass of volcanic rock known as the Topopah Spring Formation (welded tuff) (see Chapter 3, Section 3.1.3.1). The specific area in this formation where DOE would build the repository would satisfy several criteria. The primary criteria would be to (1) be within select portions of the Topopah Spring formation that have desirable properties, (2) avoid major faults for reasons related to both hydrology and seismic hazard (see Section 3.1.3.2), (3) be at least 200 meters (660 feet) below the surface, and (4) be at least 100 meters (330 feet) above the water table (TRW 1993, pages 5-99 to 5-101).

Figures 2-14, 2-15, and 2-16 show the repository footprint for the emplacement of spent nuclear fuel and high-level radioactive waste for the high, intermediate, and low thermal load scenarios, respectively. DOE would develop a high thermal load repository in the upper emplacement block, using 3 square kilometers (740 acres), with two ventilation shafts to the surface, one on the emplacement side and one on the development side (Figure 2-14). An intermediate thermal load repository would also be in the upper emplacement block, would have an area of 4.25 square kilometers (1,050 acres), and would require two ventilation shafts to the surface (Figure 2-15). A low thermal load repository would be in the upper and lower emplacement blocks and in Area 5, would use an area of approximately 10 square kilometers (2,500 acres), and would require three emplacement and two development ventilation shafts (Figure 2-16).

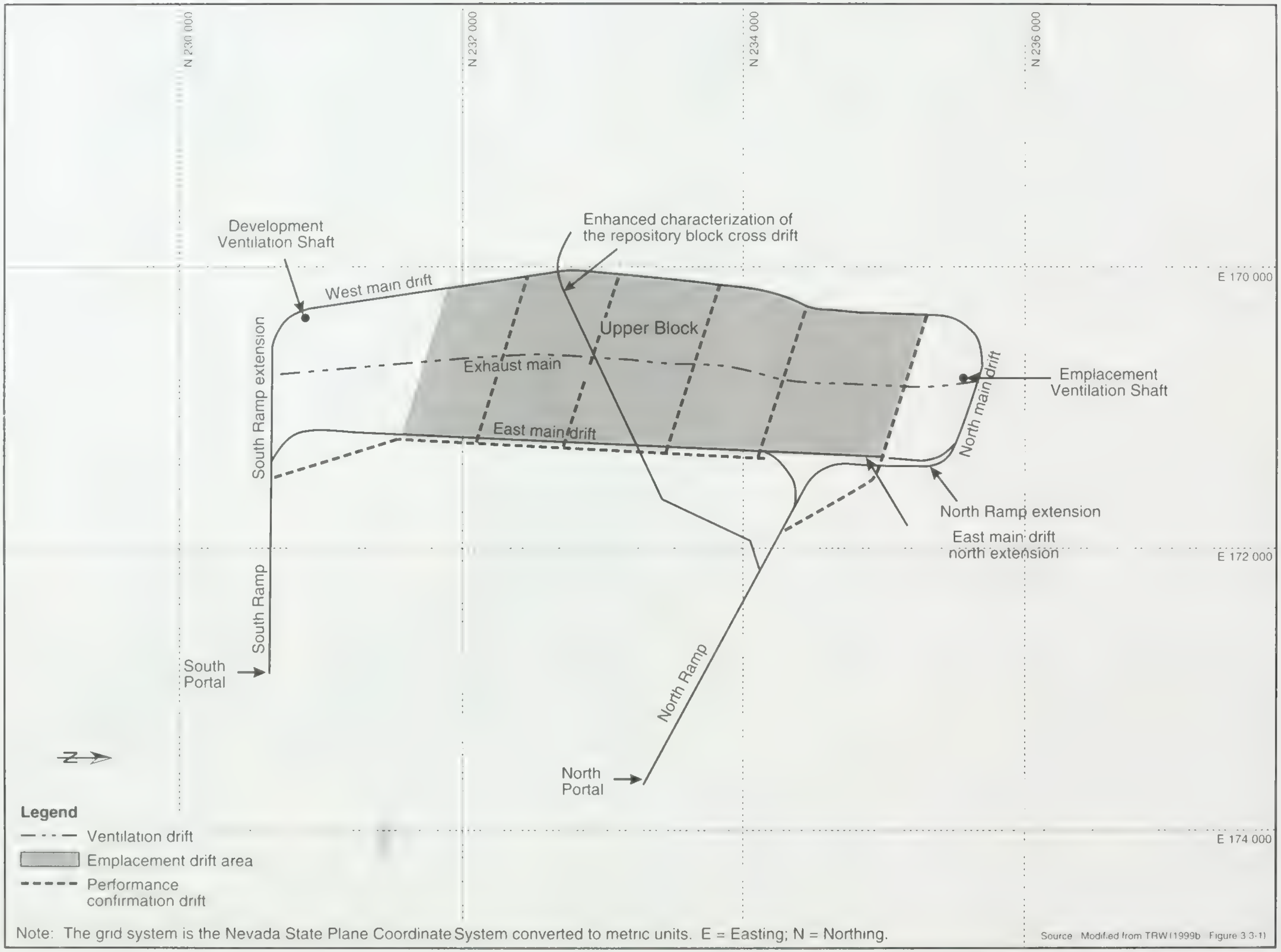


Figure 2-14. High thermal load repository layout.

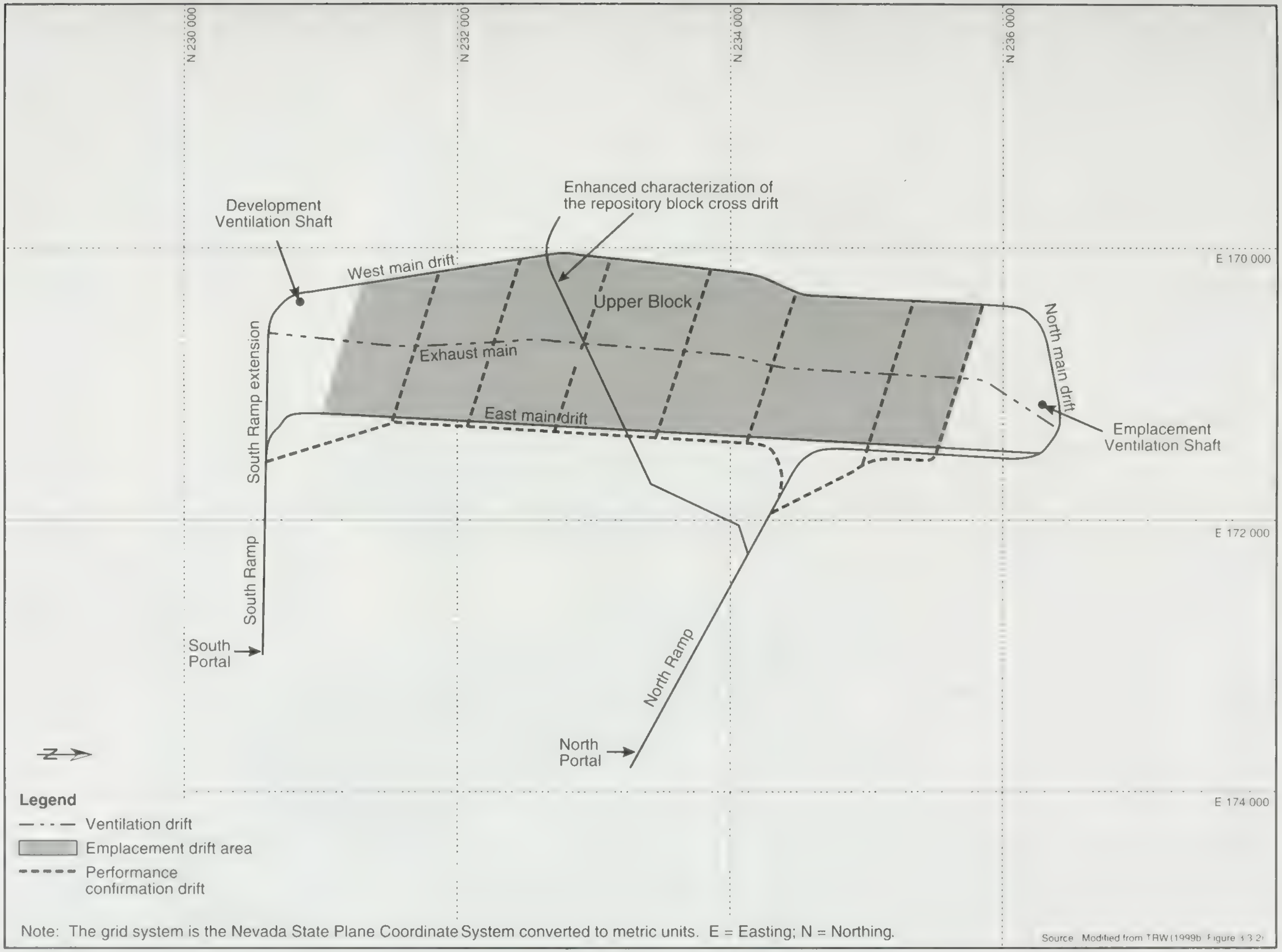


Figure 2-15. Intermediate thermal load repository layout.

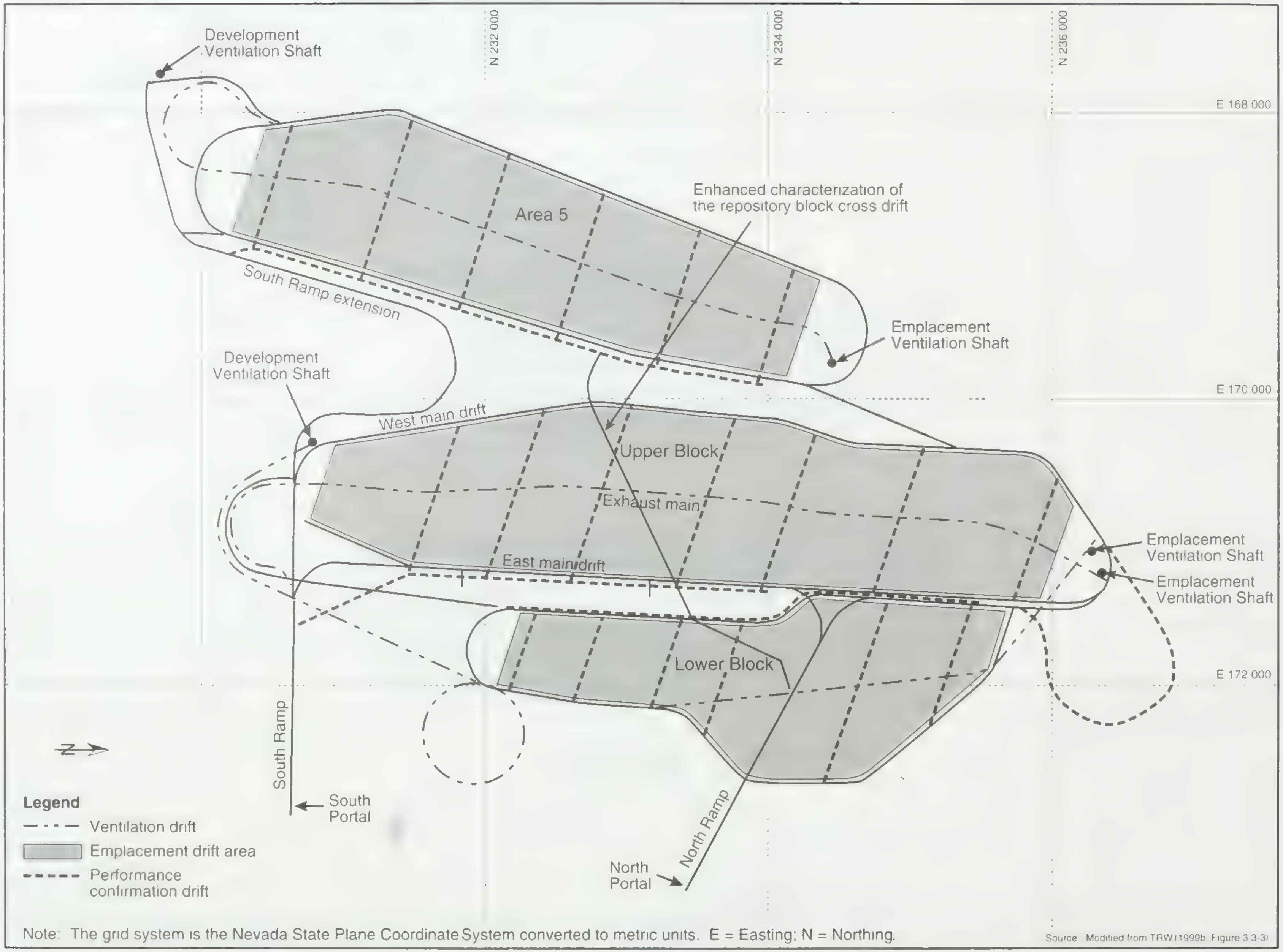


Figure 2-16. Low thermal load repository layout.

The following paragraphs describe the subsurface facility design and construction (including the ventilation system), the design of the waste packages, and waste package emplacement operations.

2.1.2.2.1 *Subsurface Facility Design and Construction*

The subsurface design would incorporate most of the drifts developed during the site characterization activities. Other areas would be excavated during the repository construction phase. Excavated openings would include gently sloping access ramps to enable rail-based movement of construction and waste package handling vehicles between the surface and subsurface, subsurface main drifts to enable the movement of construction and waste package handling vehicles, emplacement drifts for the placement of waste packages, exhaust mains to transfer air in the subsurface area, and ventilation shafts to transfer air between the surface and the subsurface. There would also be performance confirmation drifts for the placement of instrumentation to monitor emplaced waste packages (see Figures 2-14, 2-15, and 2-16).

Access ramps connecting the surface and subsurface would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by electric-powered tunnel boring machines (see Figure 2-17). Rail lines and an overhead trolley system would enable the movement of electric-powered construction and waste package handling vehicles. The North and South Ramps were developed during site characterization and would become part of the proposed repository. The North Ramp begins at the North Portal Operations Area on the surface (see Section 2.1.2.1) and extends through the subsurface to the edge of the repository area. It would support waste package emplacement operations. The South Ramp originates at the South Portal Operations Area on the surface (see Section 2.1.2.1) and extends through the subsurface to the edge of the repository area. It would support subsurface construction activities.

The main drifts for a high thermal load, shown in Figure 2-14, would include the East Main, the West Main, and the North Main. These drifts would be extended for the intermediate or low thermal load scenario. Additional main drifts would be excavated for the low thermal load scenario to provide access to other emplacement areas. Main drifts would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by tunnel boring machines. Rail lines and an overhead trolley system in the main drifts would enable the movement of electric-powered construction and waste package handling vehicles. The East Main drift was excavated as part of site characterization activities but was not lined with concrete. During the operation and monitoring phase, the main drifts would support both subsurface construction and waste package emplacement, which would occur simultaneously. Ventilation barriers creating airlocks would separate the emplacement and development sides of the repository, and the ventilation system would be designed to maintain the emplacement side at a lower pressure than the development side. This would ensure that any air leakage would be from the development side to the emplacement side.

Emplacement drifts would be 5.5-meter (18-foot)-diameter tunnels connecting the main drifts; they could have steel ribbing or be lined with concrete. These drifts would be excavated by an electrically powered tunnel boring machine. An emplacement drift would be large enough to permit the movement of waste packages over emplaced packages in the drift. Steel isolation doors at the emplacement drift entrances would prevent unauthorized human access and reduce radiation exposure to personnel. In addition, radiation shields would be placed at the ends of emplacement drifts that contained waste packages. The isolation doors would be opened and closed remotely. Figure 2-18 shows an emplacement drift branching off the East Main drift.

Exhaust main drifts would ventilate the emplacement side of the repository; they would be roughly perpendicular to and at a level below the emplacement drifts (see Figure 2-19). The exhaust main drift would connect with the emplacement drifts through a ventilation raise and would connect with an emplacement ventilation shaft. For a high thermal load configuration, a 6.7-meter (22-foot) exhaust main

Figure 2-17. Tunnel boring machine.

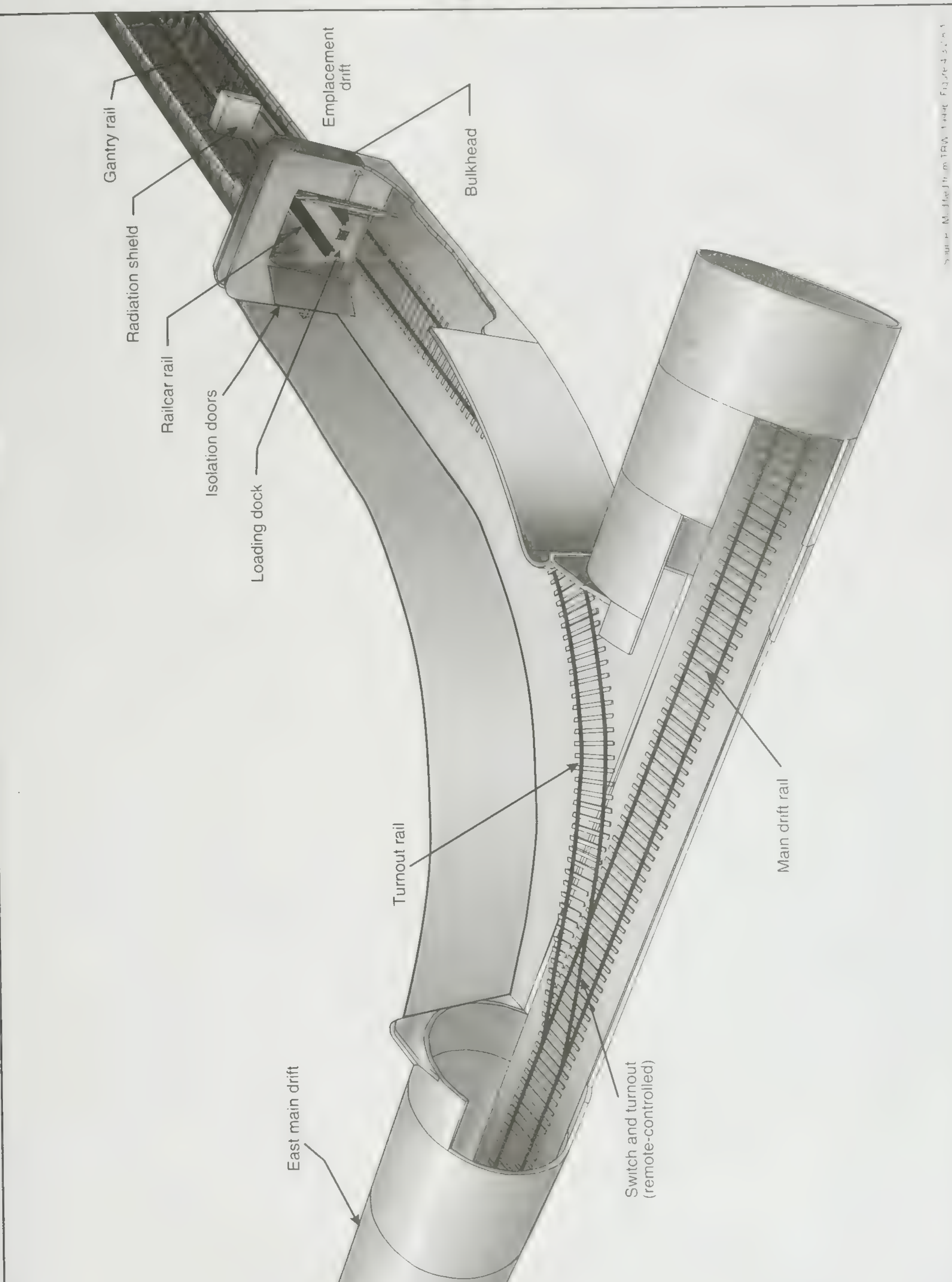


Figure 2-18. Artist's conception of emplacement drift branching from main drift.

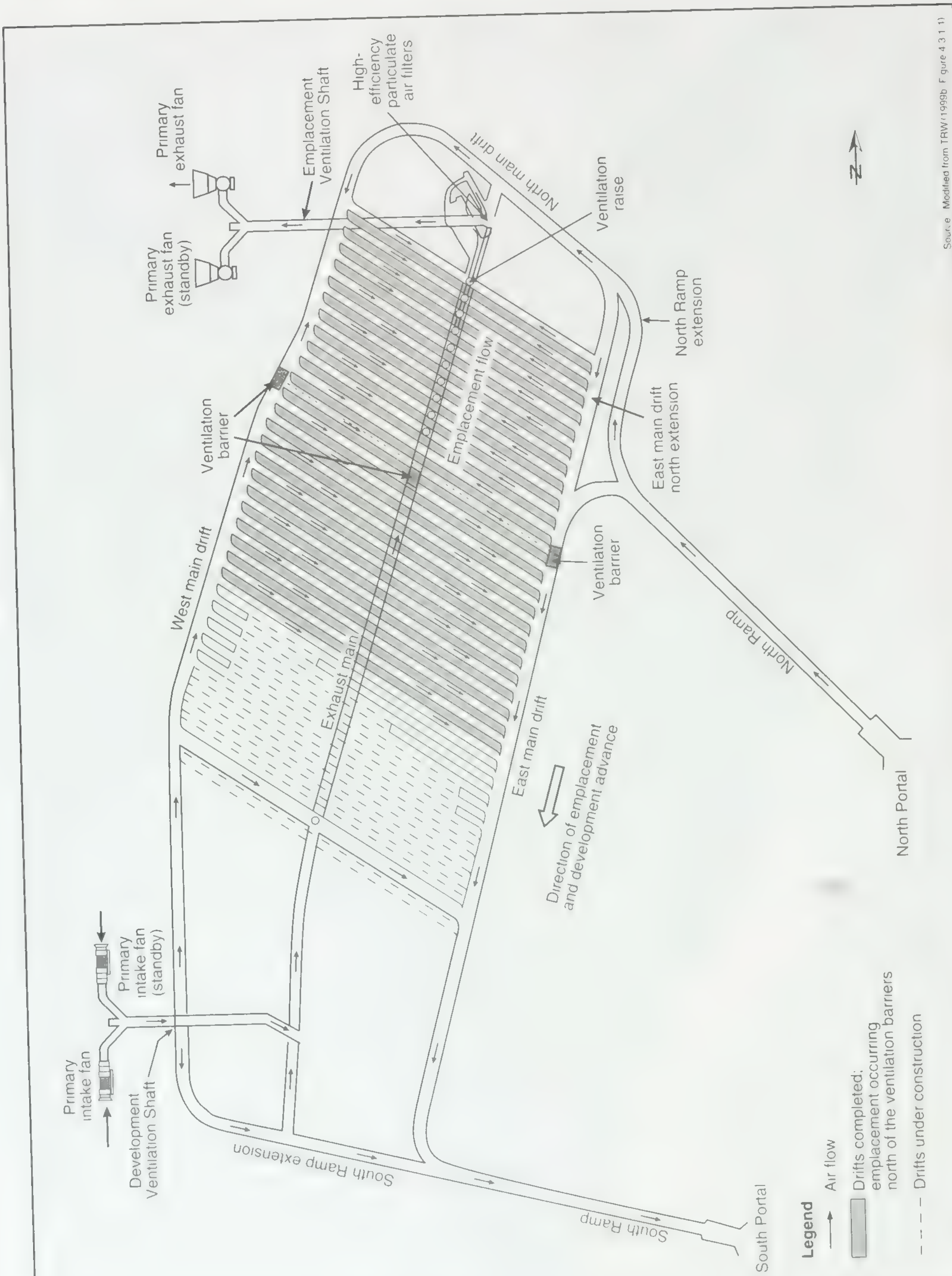


Figure 2-19. Subsurface conceptual design for ventilation air flow during construction and operations.

drift would be excavated approximately 10 meters (33 feet) below the emplacement drift. This drift would be extended for the intermediate and low thermal load scenarios. For the low thermal load scenario, other exhaust main drifts would be excavated to ventilate the additional emplacement areas. For a high thermal load configuration, DOE would excavate two 6.7-meter (22-foot)-diameter shafts for repository ventilation, an emplacement ventilation shaft at the north end and a development ventilation shaft at the south end of the upper emplacement block. An intermediate thermal load configuration would also require two shafts. These vertical shafts would extend from approximately 10 meters (33 feet) below the repository to the surface of the mountain. The emplacement ventilation shaft shown in Figure 2-19 would connect to the north end of the exhaust main drift and provide the only route for emplacement side air to leave the repository. It would be the primary ventilation exhaust airway for emplacement and monitoring activities before closure; as such, it would contain continuous radiation detection and monitoring equipment. During emplacement and monitoring operations, fans on the surface would pull air up the emplacement ventilation shaft. If the monitors detected a radioactive material leak from an emplacement drift, the exhaust air would be diverted automatically through the high-efficiency particulate air filters installed at the bottom of the emplacement ventilation shaft. Fresh air would be pulled into the repository through the North Ramp.

The development ventilation shaft, shown in Figure 2-19, would supply fresh air to the construction side of the repository. It would be the primary ventilation intake airway for subsurface development activities. Fans at the development ventilation shaft operations area would force air down to the development side of the repository. The South Ramp would be the exhaust path for air in the development side.

For a low thermal load configuration, DOE would excavate five ventilation shafts—three on the emplacement side of the repository and two on the development side. Two of the shafts on the emplacement side would contain fans to pull the air from the subsurface; the third would be an intake air shaft with no fans. Air would be pulled into the subsurface from this shaft and the North Ramp. An additional ventilation shaft would force air into the development side.

As noted above, electrically powered tunnel boring machines would excavate the emplacement drifts and most main drifts. DOE would use other mechanical excavators in areas where tunnel boring machines were impractical (for example, excavating turnouts and small alcoves) or industry-standard drill and blast techniques in limited applications where mechanical excavators were impractical. No drill and blast operations are currently envisioned, but if they were needed, care would be taken to ensure that the waste isolation properties of the mountain were not compromised. Ventilation shafts would be bored from the surface to the repository. Specialized equipment would move excavated rock in the subsurface to the conveyor system, which would move the rock from the subsurface to the excavated rock storage area on the surface. During drift excavation, water supplied to the subsurface in pipelines would be used for dust control at the excavation location and along the conveyor carrying excavated rock. Some of the water would be removed from the subsurface with the excavated rock, some would evaporate and be removed in the ventilation air, and the remainder would be collected in sumps near the point of use and pumped to the evaporation pond at the South Portal. DOE could recycle the water discharged to the evaporation pond for surface dust suppression activities. Controls would be established, as necessary, to ensure that water application for subsurface (and surface) dust control would not affect repository performance.

2.1.2.2.2 *Waste Package Design*

The function of the waste package changes over the repository lifetime. During the operation and monitoring phase, the disposal containers or waste packages would function as the vessels for safely handling, emplacing, and retrieving (if necessary) their contents. After closure, the waste packages would be the primary engineered barrier to inhibit the release of radioactive material to the environment.

DOE is developing specific waste package designs for uncanistered spent nuclear fuel assemblies, canistered spent nuclear fuel assemblies, and high-level radioactive waste canisters (Figure 2-20). The waste packages would be cylindrical containers and, in the preliminary conceptual design, range from 3.7 meters (12 feet) to 6.2 meters (20 feet) long and 1.25 to 2.0 meters (4.1 to 6.6 feet) in diameter. The waste packages of commercial spent nuclear fuel would hold as many as 21 pressurized-water reactor fuel assemblies or 44 boiling-water reactor fuel assemblies. There would be two general waste package designs for other types of spent nuclear fuel. These two designs would hold either a canister containing assemblies of naval spent nuclear fuel, or several canisters containing DOE spent nuclear fuel assemblies. There would be two general co-disposal waste package loading options, which would hold either five high-level radioactive waste canisters with an additional canister containing DOE spent nuclear fuel assemblies, or five canisters containing both high-level radioactive waste and immobilized plutonium waste forms. In addition, there would be waste packages that would contain only high-level radioactive waste.

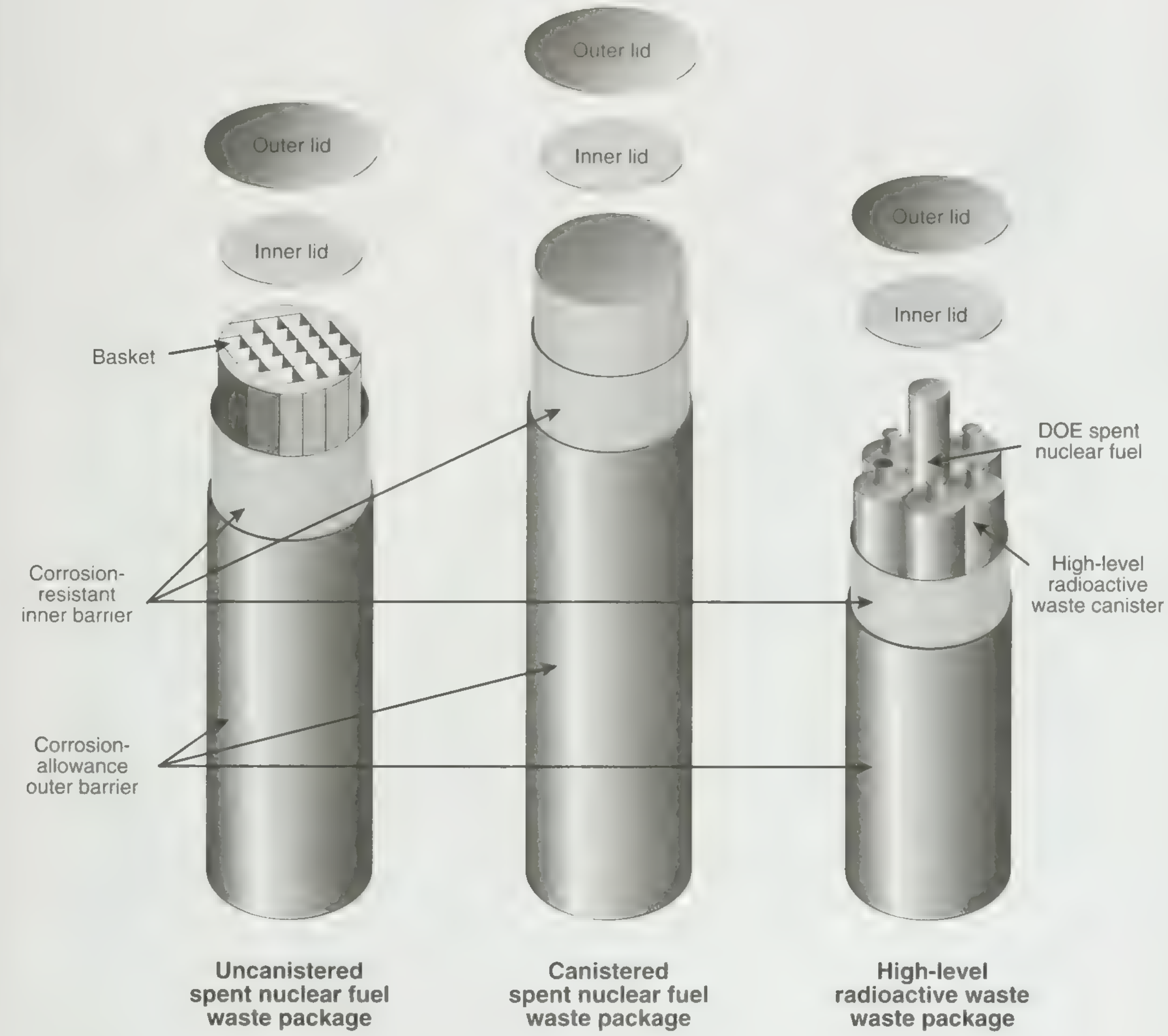
The preliminary conceptual design of the waste packages would have two layers: a structurally strong outer layer of carbon steel about 10 centimeters (4 inches) thick, and a corrosion-resistant inner layer of high-nickel alloy (Alloy 22) about 2 centimeters (0.79 inch) thick. These two layers would work together to preserve the integrity of the waste package for thousands of years.

Commercial spent nuclear fuel, DOE spent nuclear fuel, and immobilized plutonium contain *fissile material*, which is material capable, in principle, of sustaining a fission chain reaction. For a self-sustaining chain reaction to take place, a critical mass of fissile material — uranium-233 or -235 or one of several plutonium isotopes — must be arranged in a critical configuration. Waste packages are loaded with fissile material and neutron absorbers, if needed, so criticality cannot occur even in the unlikely event that the waste package somehow became full of water.

The waste packages would be placed horizontally on supports in the emplacement drifts (Figure 2-21). The supports would be steel and concrete structures that would hold the waste packages above the drift floor. DOE would place approximately 10,000 to 11,000 waste packages, which would include both spent nuclear fuel and high-level radioactive waste, in the repository. For the high thermal load scenario, the emplacement drifts would be spaced approximately 28 meters (92 feet) apart; for the intermediate thermal load scenario, they would be spaced approximately 28 to 40 meters (92 to 130 feet) apart; and for the low thermal load scenario, they would be spaced approximately 38 meters (125 feet) apart. In the emplacement drifts, DOE would then use the optimum spacing of waste packages based on their actual heat load; therefore, spacing would be greatest for the low thermal load scenario.

2.1.2.2.3 *Waste Package Emplacement Operations*

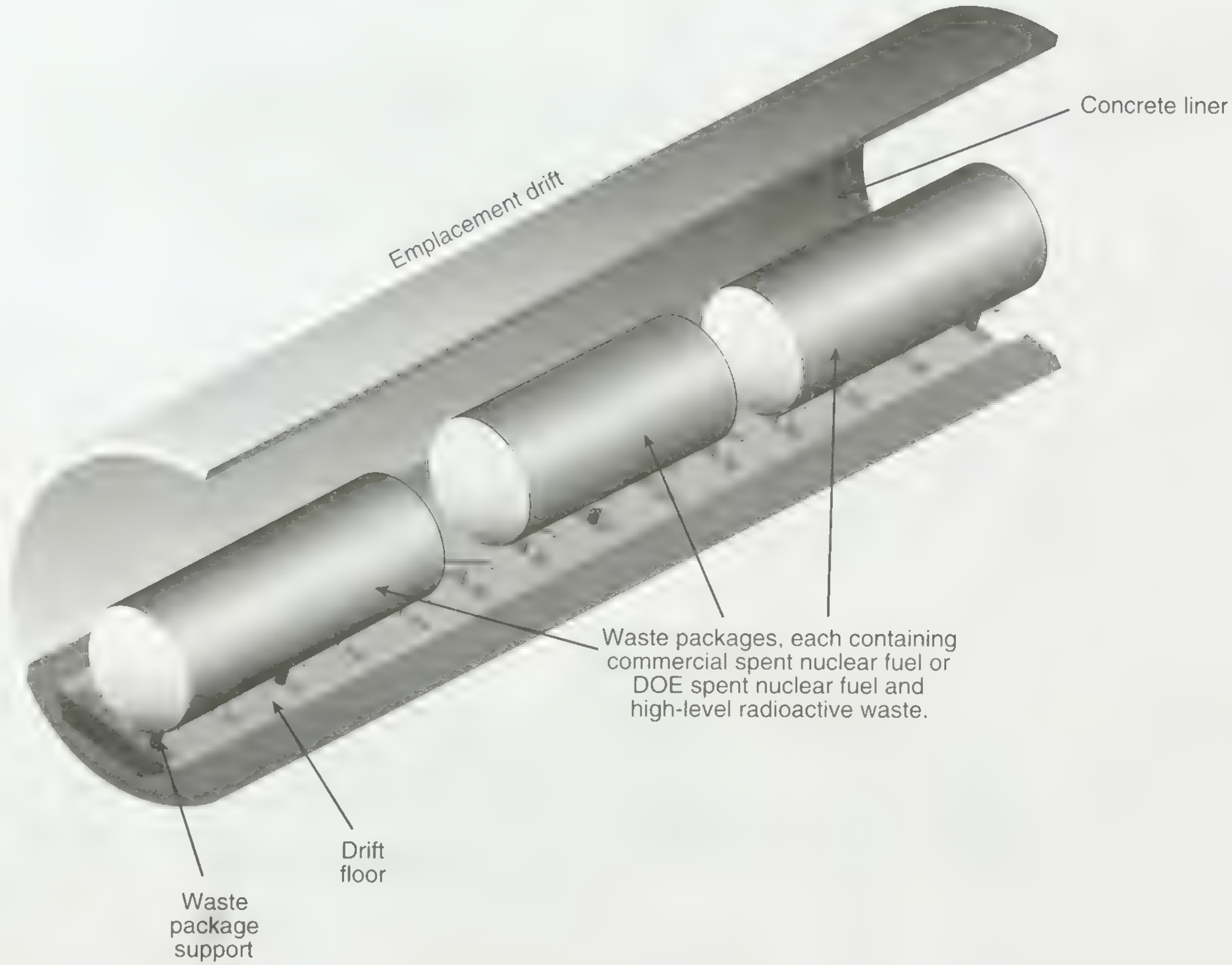
The transport of each waste package to the subsurface would start after the loading of a waste package on a reusable railcar and the loading of that railcar in a shielded waste package transporter in the Waste Handling Building (Figure 2-22). The transporter would be coupled at its closed end to a primary electric powered locomotive (trolley). A secondary electric powered locomotive would be coupled to the door end of the waste package transporter outside the Waste Handling Building. All waste packages would be transported underground through the North Ramp to the emplacement area main drift (Figure 2-23). On arrival at the emplacement drift, the secondary locomotive would be uncoupled from the transporter, and the transporter would be pushed into the emplacement drift turnout by the primary locomotive and stopped short of the isolation doors and loading dock. The doors would be opened remotely, as would the transporter doors. The transporter would be moved to align with the loading dock. The waste package would be moved on the railcar to the emplacement drift loading dock. The gantry would lift the waste package from the railcar and carry it to its emplacement location. The empty railcar would be returned to



Note: Waste packages would range in size from 3.7 to 6.2 meters (12 to 20 feet) long and 1.25 to 2.0 meters (4.1 to 6.6 feet) in diameter. They would range in weight from 35,000 kilograms (77,000 pounds) to 83,000 kilograms (183,000 pounds).

Source: Modified from DOE (1998a, Volume 3 Figure 2-3)

Figure 2-20. Potential waste package designs for spent nuclear fuel and high-level radioactive waste.



Note: Spacing between packages is for illustration only. The actual spacing would be determined as a function of the final repository thermal load design.

Sources: Modified from DOE (1998a, Volume 2 Figure 5-1)

Figure 2-21. Conceptual design of waste packages in emplacement drift.

Figure 2-22. Artist's conception of operations to move waste underground (view of Waste Handling Building and North Portal).

(1) Emplacement drift
(2) Emplacement drift isolation door
(3) Waste package transporter (waste package waiting for gantry)
(4) Electric-powered locomotive (trolley)
(5) Turnout

Sources: Modified from DOE (1998a, Overview, page 14)

Figure 2-23. Artist's conception of repository underground facilities and operation.

the transporter, the isolation doors would be closed remotely, and the empty transporter with locomotives coupled front and rear would be returned to the surface for reuse.

2.1.2.3 Repository Closure

Permanent closure of the proposed repository would include closing the subsurface facilities, decontaminating and decommissioning the surface facilities, reclaiming the site, and establishing institutional barriers. This EIS assumes that repository closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement). The time to complete repository closure would vary from about 6 years for the high and intermediate thermal load scenarios to about 15 years for the low thermal load scenario.

The closure of the subsurface repository facilities would include the removal and salvage of equipment and materials; filling of the main drifts, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and boreholes. Filling operations would require surface operations to obtain fill material from the excavated rock pile or other source, and processing (screening, crushing, and possibly washing) the material to obtain the required particle size. Fill material would be transported on the surface in trucks and underground in open gondola railcars. A fill placement system would place the material in the underground main drifts and ramps. Seals for shafts, ramps, and boreholes would be strategically located to reduce radionuclide migration over extended periods, and so that they could not become pathways that could compromise the repository's postclosure performance. Seal materials and placement methods would be selected to reduce, to the extent practicable, the creation of preferential pathways for groundwater to contact the waste packages and the migration of radionuclides through existing pathways.

Decommissioning surface facilities would include decontamination activities, if required, and facility dismantlement and removal. Equipment and materials would be salvaged, recycled, or reused, if possible. Site reclamation would include restoring the site to as near its preconstruction condition as practicable. Reclamation could require the recontouring of disturbed surface areas, surface backfill, soil buildup and reconditioning, site revegetation, site water course configuration, and erosion control.

DOE would use institutional controls, including land records and warning systems, to limit or prevent intentional and unintentional activities in and around the closed repository. The repository area would be identified by monuments that would be designed, fabricated, and placed to be as permanent as practicable. Provisions could be added for postclosure monitoring.

2.1.2.4 Performance Confirmation Program

Performance confirmation refers to the program of tests, experiments, and analyses that DOE would conduct to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that long-term performance objectives have been met. The performance confirmation program, which would continue through the closure phase, would include elements of site testing, repository testing, repository subsurface support facilities construction, and waste package testing. Some of these activities would be a continuation of activities that began during site characterization. The data collection focus of the performance confirmation program initially would be to collect additional information to support enhanced confidence in the data used in the License Application. After the granting of licenses, the activities primarily would focus on monitoring and data collection for parameters important to terms and conditions of the license. The types of data important in the performance confirmation programs could include:

- Thermal response of the rock mass
- Air temperature and relative humidity in the emplacement drifts

- Possible emanation of radioactive gases from the emplacement drifts
- Condition of the waste packages and emplacement drifts
- Placement and recovery of test amounts of sample materials in the emplacement drifts
- Saturated zone monitoring
- Possible groundwater flow into the emplacement drifts and evidence of standing water accumulating in the emplacement drifts
- Air permeability, stress, and deformation and displacement of the rocks around the emplacement drifts
- Soil and rock temperature around the repository
- Moisture content, vapor content and humidity, fluid temperature, and air pressure in the rock adjacent to the emplacement drifts that would be most strongly affected by the presence of the emplaced waste

Performance confirmation drifts would be built about 15 meters (50 feet) above the emplacement drifts (see Figures 2-14, 2-15, and 2-16). DOE would drill boreholes from the performance confirmation drifts that would approach the rock mass near the emplacement drifts; instruments in these boreholes would gather data on the thermal, mechanical, hydrological, and chemical characteristics of the rock after waste emplacement. DOE would acquire performance confirmation data by sampling and mapping, from instruments in performance confirmation drifts or along the perimeter mains, ventilation exhaust monitoring, remote inspection systems in emplacement drifts, and possible recovery of waste packages for testing.

The performance confirmation program data would be used to evaluate total system performance and to confirm predicted system response. If the data determined that actual conditions differed from those predicted, the results could support further evaluation of the impacts of actual conditions on the long-term performance of the repository system.

2.1.3 TRANSPORTATION ACTIVITIES

Under the Proposed Action, DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository. The Naval Nuclear Propulsion Program would transport naval spent nuclear fuel from the Idaho National Engineering and Environmental Laboratory to the repository. Transportation activities would include the loading of these materials for shipment at generator sites (Section 2.1.3.1), transportation of the materials to the Yucca Mountain site by truck, rail, or possibly barge [see Sections 2.1.3.2 (National) and 2.1.3.3 (Nevada)], and shipping cask manufacturing, maintenance, and disposal (Section 2.1.3.4).

2.1.3.1 Loading Activities at Commercial and DOE Sites

This EIS evaluates the loading of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites for transportation to the proposed repository at Yucca Mountain. Activities would include removing the spent nuclear fuel or high-level radioactive waste from storage, loading it in a shipping cask, and placing the cask on a vehicle (see Figures 2-24 and 2-25) for shipment to the repository. This EIS assumes that at the time of shipment the spent nuclear fuel and high-level radioactive waste would be in a form that met approved acceptance and disposal criteria for the repository.

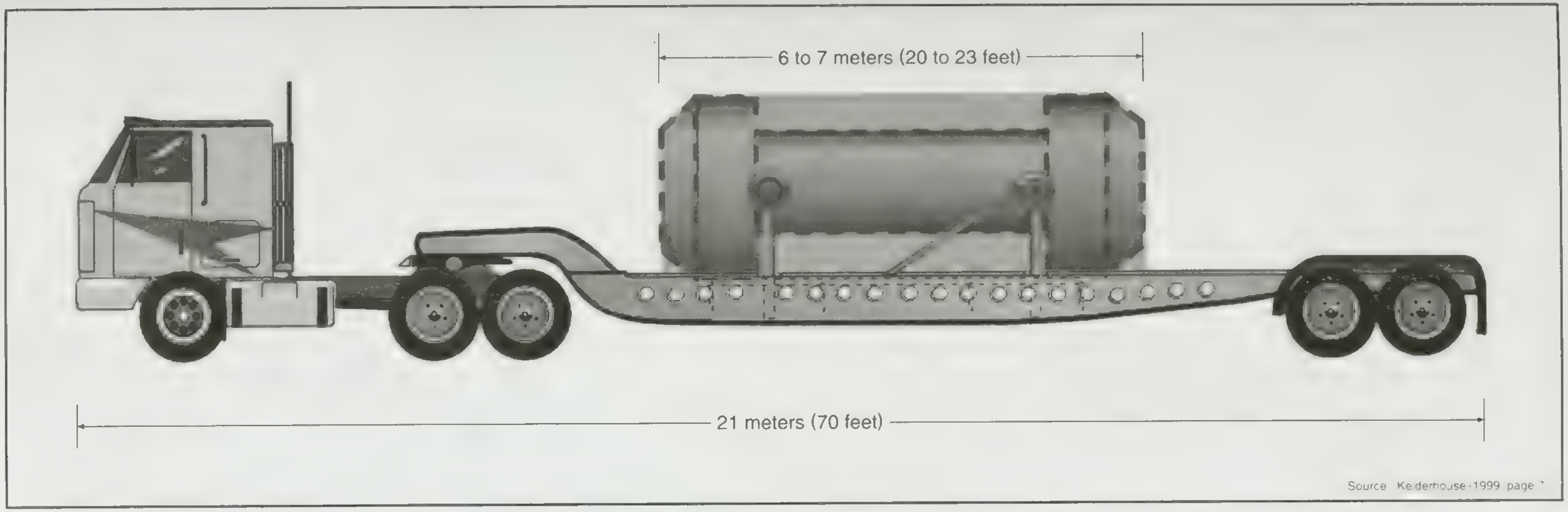


Figure 2-24. Artist's conception of a truck cask on a legal-weight tractor-trailer truck.

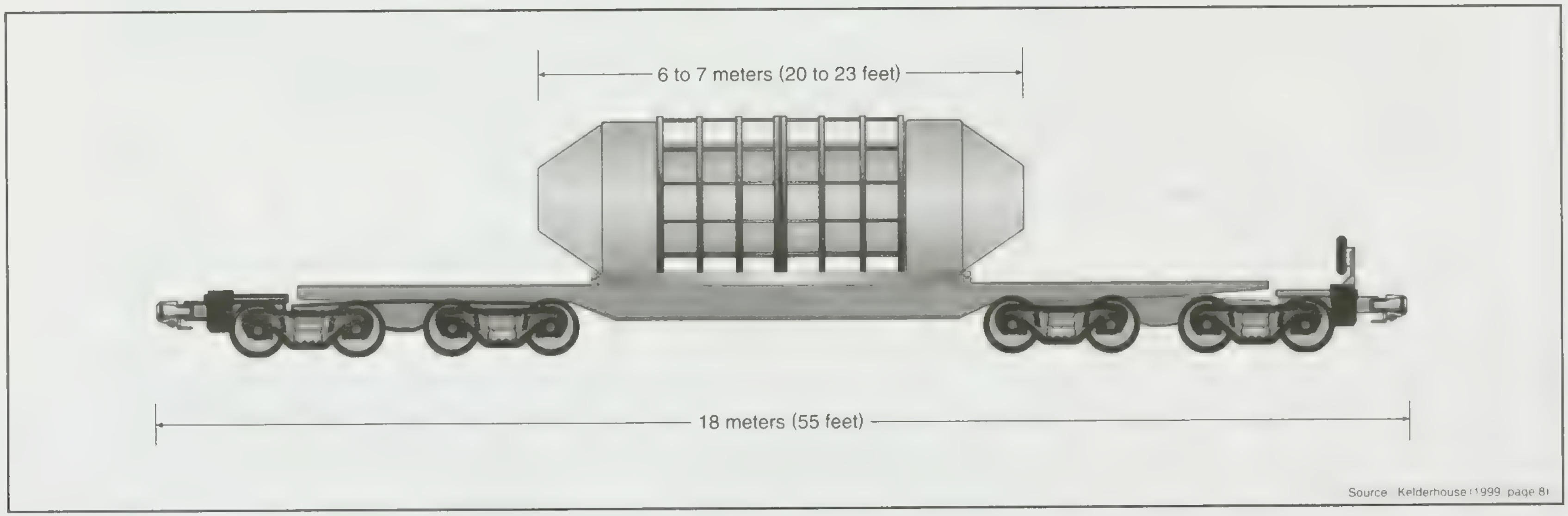


Figure 2-25. Artist's conception of a large rail cask on a railcar.

2.1.3.2 National Transportation

National transportation includes the transport of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site using existing highways (see Figure 2-26) and railroads (see Figure 2-27). Heavy-haul trucks could be used to transport spent nuclear fuel from commercial sites that did not have rail access to a nearby rail access point. Such sites on navigable waterways could use barges to deliver spent nuclear fuel to a nearby rail access point. The transportation of spent nuclear fuel and high-level radioactive waste to the repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission, as well as applicable state and local regulations.

DOE has developed TRANSCOM, a satellite-based transportation tracking and communications system, to track current truck and rail shipments. Using the TRANSCOM system, DOE would monitor shipments of spent nuclear fuel and high-level radioactive waste to the repository at frequent intervals. This or a similar system could provide users (for example, DOE, the Nuclear Regulatory Commission, and state and tribal governments) with information about shipments to the repository and would enable communication between the vehicle operators and a central communication station. In heavily populated areas, armed escorts would be required for highway and rail shipments (10 CFR 73.37).

Section 180(c) of the Nuclear Waste Policy Act requires DOE to provide technical and financial assistance to states and tribes for training public safety officials in jurisdictions through which it plans to transport spent nuclear fuel and high-level radioactive waste. The training is to include procedures for the safe routine transportation of these materials and for emergency response situations. DOE is developing the policy and procedures for implementing this assistance and has started discussions with the appropriate organizations. The Department would institute these plans before beginning shipments to the repository. In the event of an incident involving a shipment of spent nuclear fuel or high-level radioactive waste, the transportation vehicle crew would notify local authorities and the central communications station monitoring the shipment. DOE would make resources available to local authorities as appropriate to mitigate such an incident.

2.1.3.2.1 *National Transportation Shipping Scenarios*

DOE would ship spent nuclear fuel and high-level radioactive waste from commercial and DOE sites in some combination of legal-weight truck, rail, heavy-haul truck, and possibly barge. This EIS considers two national transportation scenarios, which for simplicity are referred to as the mostly legal-weight truck scenario and the mostly rail scenario. These scenarios illustrate the broadest range of operating conditions relevant to potential impacts to human health and the environment. Table 2-2 summarizes these scenarios, and Appendix J provides additional details.

Table 2-2. National transportation scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail
Commercial SNF	100% by legal-weight truck	About 80% by rail; about 20% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail
DOE SNF	Mostly legal-weight truck; includes about 300 naval SNF shipments from INEEL to Nevada by rail	100% by rail

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

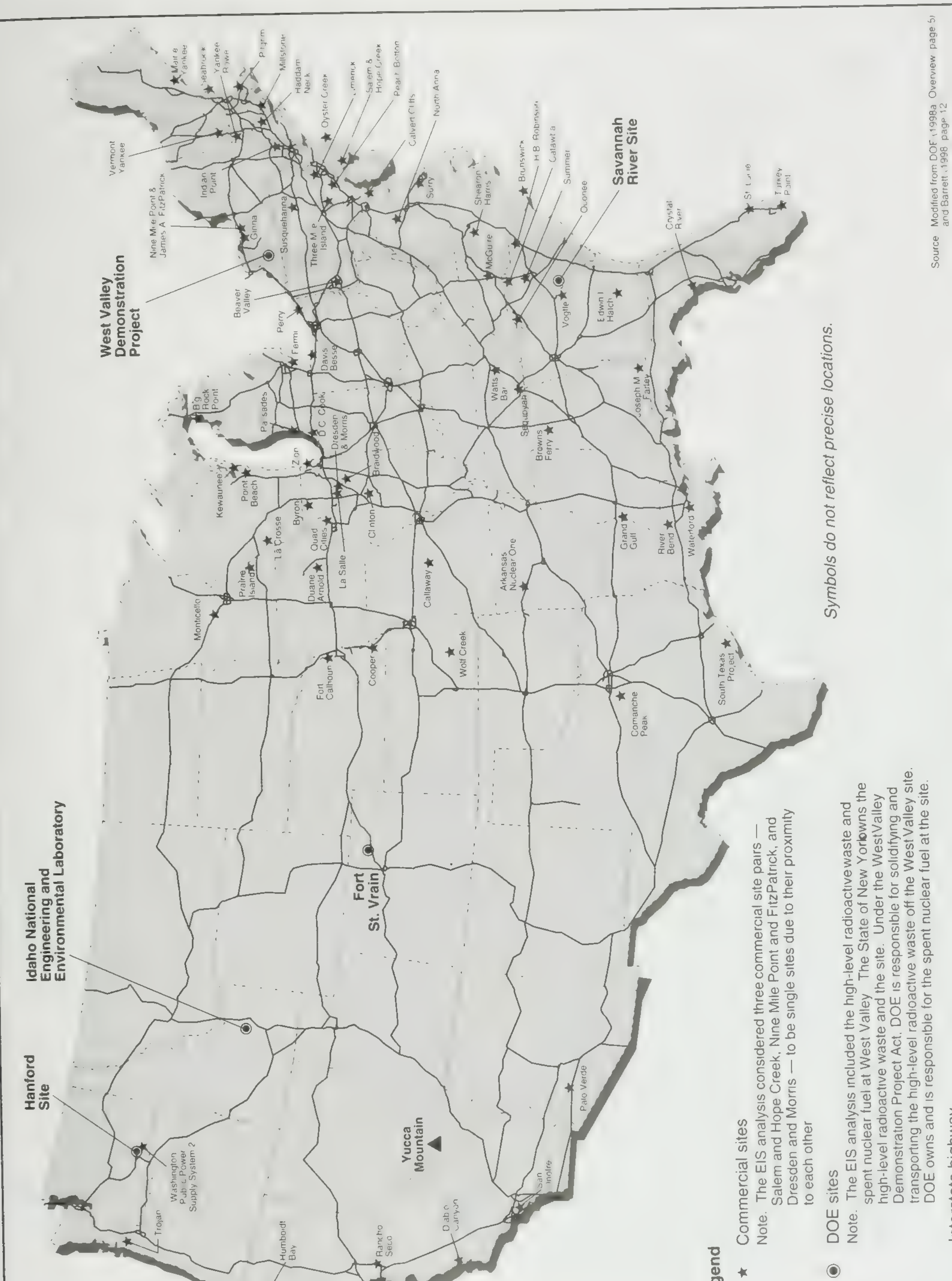


Figure 2-26. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

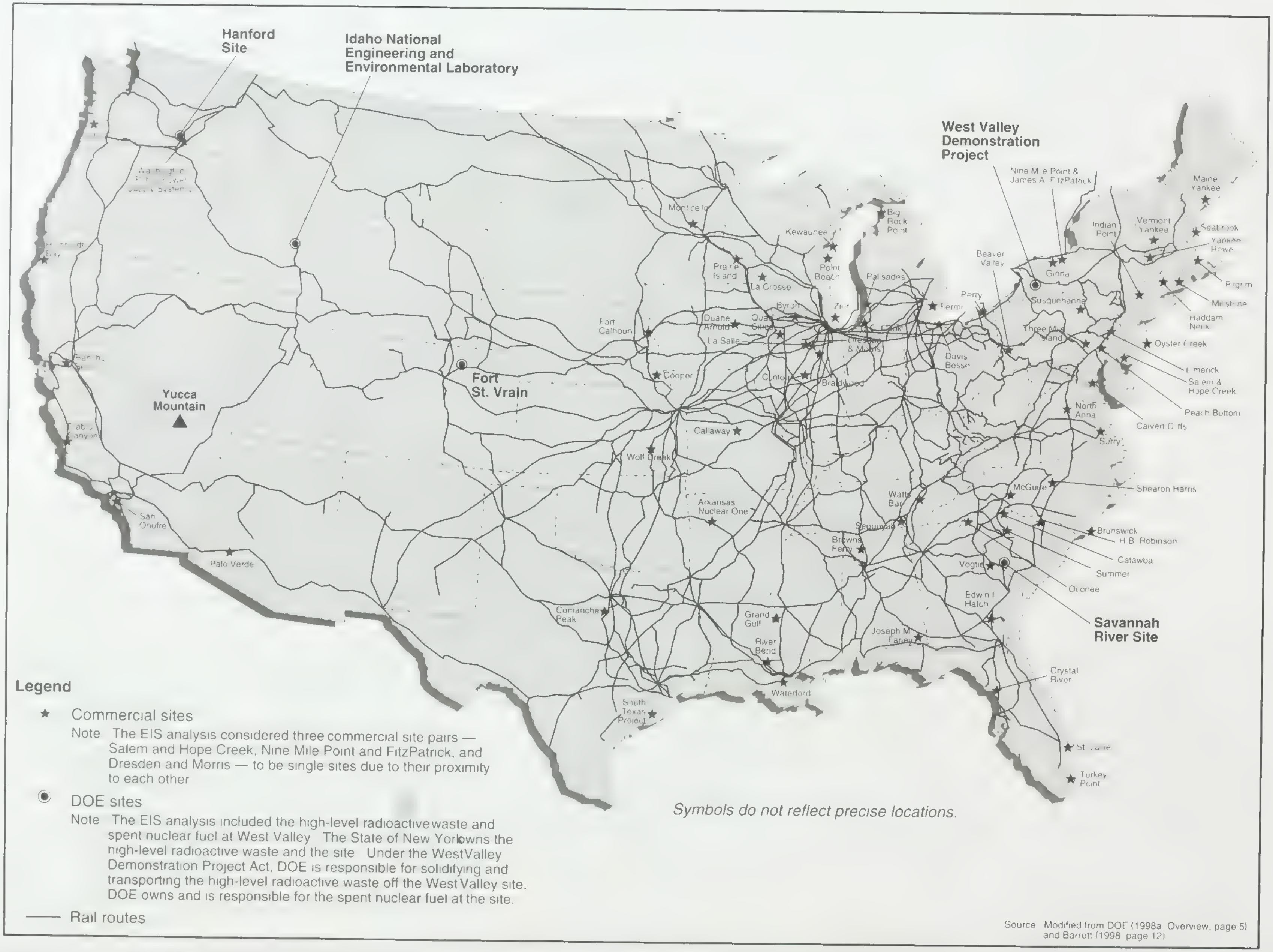


Figure 2-27. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

2.1.3.2.2 *Mostly Legal-Weight Truck Shipping Scenario*

Under this scenario, DOE would ship all high-level radioactive waste and most spent nuclear fuel from commercial and DOE sites to the Yucca Mountain site by legal-weight truck. About 50,000 shipments of these materials would travel on the Nation's Interstate Highway System during a 24-year period. There would be about 38,000 commercial spent nuclear fuel shipments and about 12,000 shipments of DOE spent nuclear fuel and high-level radioactive waste. The exception would be about 300 shipments of naval spent nuclear fuel that would travel from the Idaho National Engineering and Environmental Laboratory to Nevada by rail. [The Navy prepared an EIS (USN 1996a, all) and issued two Records of Decision (62 *FR* 1095, January 8, 1997; 62 *FR* 23770, May 1, 1997) on its spent nuclear fuel.]

Truck shipments would use Nuclear Regulatory Commission-certified, reusable shipping casks secured on legal-weight trucks (Figure 2-24). With proper labels and vehicle placards (hazard identification) and vehicle and cask inspections, a truck carrying a shipping cask of spent nuclear fuel or high-level radioactive waste would travel to the repository on highway routes selected in accordance with U.S. Department of Transportation regulations (49 CFR 397.101), which require the use of preferred routes. These routes include the Interstate Highway System, including beltways and bypasses. Alternative routes could be designated by states and tribes following Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with affected local jurisdictions and with any other affected states.

Shipments of naval spent nuclear fuel would travel by rail in reusable shipping casks certified by the Nuclear Regulatory Commission. These shipments would use applicable and appropriate placards and inspection procedures.

2.1.3.2.3 *Mostly Rail Shipping Scenario*

Under this scenario, DOE would ship most spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear sites that do not have the capability to load large-capacity rail shipping casks. Those sites would ship spent nuclear fuel to the repository by legal-weight truck. Commercial sites that have the capability to load large-capacity rail shipping casks but not rail access could use heavy-haul trucks or barges to transport their spent nuclear fuel to a nearby rail line. Under this scenario, about 11,000 railcars of spent nuclear fuel and high-level radioactive waste would travel on the nationwide rail network over a period of 24 years. Rail shipments would consist of Nuclear Regulatory Commission-certified, reusable shipping casks secured on railcars (see Figure 2-25). In addition, there would be about 2,600 legal-weight truck shipments. All shipments would be marked with the appropriate labels and placards and would be inspected in accordance with applicable regulations.

Some of the logistics of rail transportation to the repository would depend on whether DOE used general or dedicated freight service. General freight shipments of spent nuclear fuel and high-level radioactive waste would be part of larger trains carrying other commodities. A number of transfers between trains could occur as a railcar traveled to the repository. The basic infrastructure and activities would be similar between general freight and dedicated trains. However, dedicated train service would contain only railcars destined for the repository. In addition to railcars carrying spent nuclear fuel or high-level radioactive waste, there would be buffer and escort cars, in accordance with Federal regulations. DOE would use a satellite-based system to monitor all spent nuclear fuel shipments (see Section 2.1.3.2).

TERMS RELATED TO RAIL SHIPPING

General freight rail service: A train that handles a number of commodities. Railcars carrying spent nuclear fuel or high-level radioactive waste could switch in railyards or on sidings to a number of trains as they traveled from commercial and DOE sites to Nevada.

Dedicated freight rail service: A train that handles only one commodity (in this case, spent nuclear fuel or high-level radioactive waste). Use of a separate train with its own crew carrying spent nuclear fuel or high-level radioactive waste would avoid switching railcars between trains.

Buffer cars: Railcars placed in front and in back of those carrying spent nuclear fuel or high-level radioactive waste to provide additional distance from possibly occupied railcars. Federal regulations (49 CFR 174.85) require the separation of a railcar carrying spent nuclear fuel or high-level radioactive waste from a locomotive, occupied caboose, or carload of undeveloped film by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

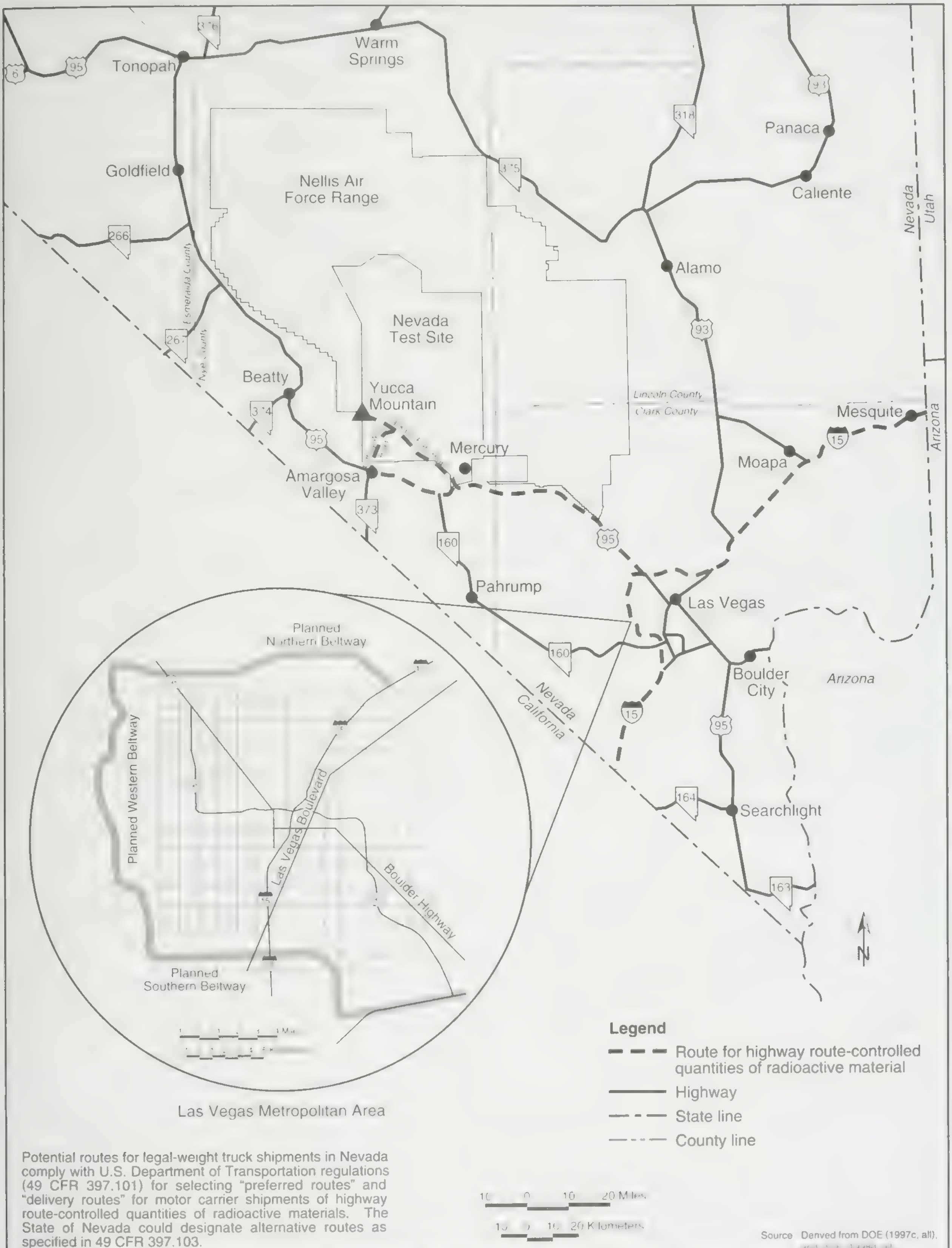
Escort cars: Railcars in which escort personnel (for example, security personnel) would reside on trains carrying spent nuclear fuel or high-level radioactive waste.

2.1.3.3 Nevada Transportation

Nevada transportation is part of national transportation, but the EIS also discusses it separately. Depending on how a shipment was transported, DOE could use one of three options or modes of transportation in Nevada: legal-weight trucks, rail, or heavy-haul trucks. Legal-weight truck shipments arriving in Nevada would travel directly to the Yucca Mountain site. Two Interstate highways cross Nevada—I-80 in the north and I-15 in the south. I-15, the closest Interstate highway to the proposed repository, travels through Salt Lake City, Utah, to southern California, passing through Las Vegas. Figure 2-28 shows the existing highway infrastructure in southern Nevada. The EIS analysis assumed that the proposed Interstate bypass around the urban core of Las Vegas (the Las Vegas Beltway) would be operational before 2010.

Shipments arriving in Nevada by rail would travel to the repository site by rail or heavy-haul truck (legal-weight trucks could not be used due to the size and weight of the rail shipping casks). Existing rail lines in the State include two northern routes and one southern route; the Southern Pacific Railroad owns one of the northern routes and the Union Pacific Railroad owns the other northern route and the southern route. The northern routes pass through or near the cities of Elko, Carlin, Battle Mountain, and Reno. The southern route runs through Salt Lake City, Utah, to Barstow, California, passing through Caliente, Las Vegas, and Jean, Nevada. Figure 2-29 shows the Nevada rail infrastructure. Rail access is not currently available to the Yucca Mountain site, so DOE would have to build a branch rail line from an existing mainline railroad to the site or transfer the rail cask to a heavy-haul truck at an intermodal transfer station for transport to the repository.

To indicate distinctions between available transportation options or modes in Nevada and to define the range of potential impacts associated with transportation in the State, this EIS analyzes three transportation scenarios: the first, associated with the national legal-weight truck scenario, is a Nevada legal-weight truck scenario; the second and third, both associated with the national rail scenario, are rail transport directly to the Yucca Mountain site, and an intermodal transfer from railcar to heavy-haul truck for travel to the site. Table 2-3 summarizes the Nevada transportation scenarios.



Potential routes for legal-weight truck shipments in Nevada comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting "preferred routes" and "delivery routes" for motor carrier shipments of highway route-controlled quantities of radioactive materials. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

Figure 2-28. Southern Nevada highways.

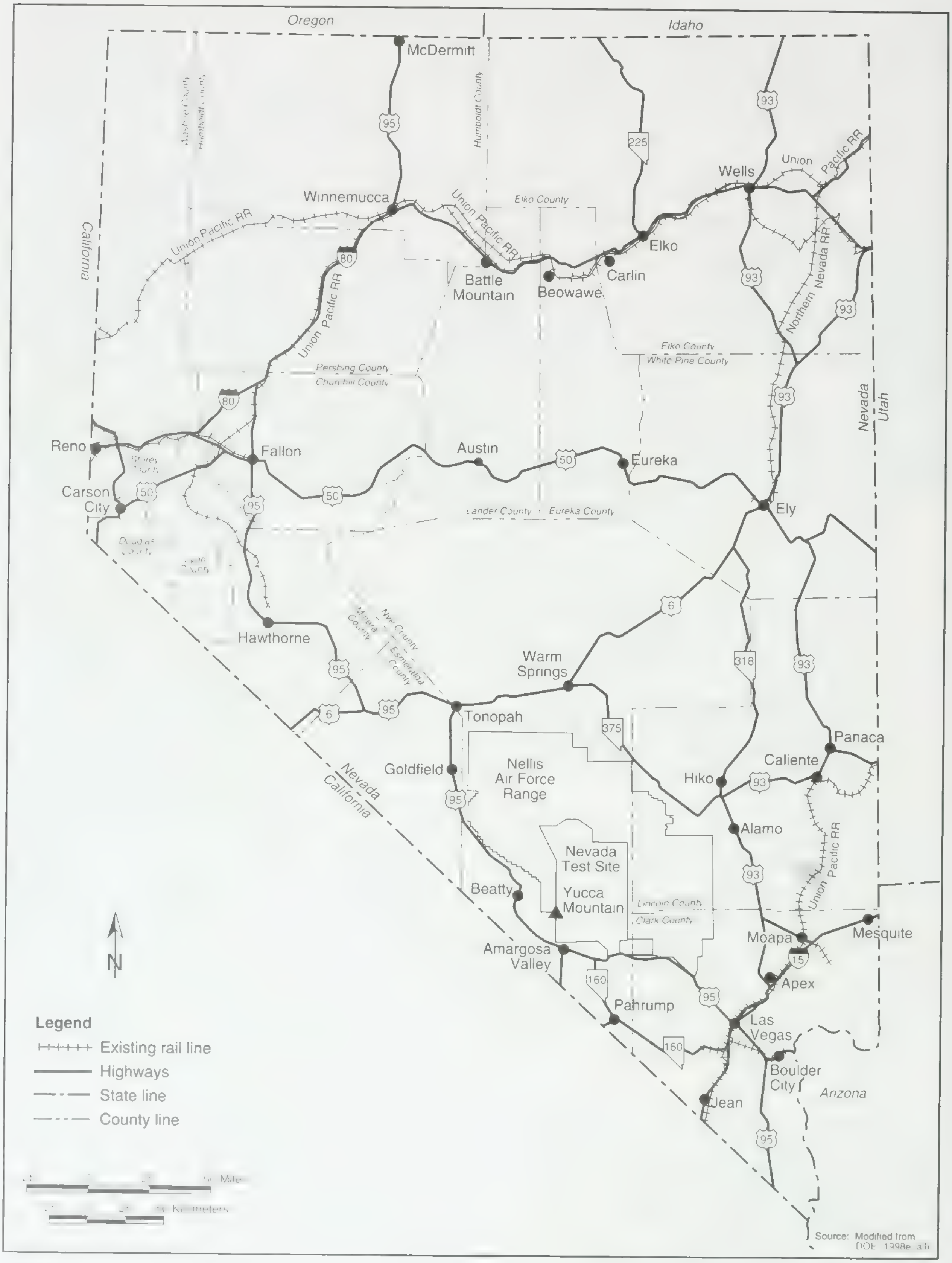


Figure 2-29. Existing Nevada rail lines.

Table 2-3. Nevada transportation shipping scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail	Mostly heavy-haul truck[b]
Commercial SNF	100% by legal-weight truck	About 80% by rail; about 20% by legal-weight truck	About 80% by heavy-haul truck; about 20% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail	100% by heavy-haul truck
DOE SNF	Mostly by legal-weight truck; includes about 300 naval SNF shipments by rail and heavy-haul truck	100% by rail	100% by heavy-haul truck

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.

b. Rail shipment to intermodal transfer station, and heavy-haul truck shipment from intermodal transfer station to the repository.

The following sections describe the Nevada transportation scenarios and the implementing alternatives DOE is considering for a new branch rail line or a new intermodal transfer station and associated highway route for heavy-haul trucks. Detailed engineering descriptions are based on TRW (1999d, all), unless otherwise noted.

2.1.3.3.1 *Nevada Legal-Weight Truck Scenario*

Under this scenario, DOE would use legal-weight trucks in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. Naval spent nuclear fuel would be transported to Nevada by rail. In Nevada, DOE would use heavy-haul trucks to transport these 300 shipments. DOE would establish an intermodal transfer capability and an associated heavy-haul shipment capability (see Section 2.1.3.3.3).

Legal-weight truck shipments would use existing routes that satisfy regulations of the U.S. Department of Transportation for the shipment of highway route-controlled quantities of radioactive materials (49 CFR 397.101). Legal-weight trucks would enter Nevada on I-15 from the north or south, bypass the Las Vegas area on the proposed beltway, and travel north on U.S. 95 to the Nevada Test Site and then to the Yucca Mountain site (Figure 2-28).

2.1.3.3.2 *Nevada Rail Scenario*

Under this scenario, DOE would construct and operate a branch rail line in Nevada. Based on previous studies (described in Section 2.3), DOE has narrowed its consideration for a new branch rail line to five potential rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. These rail corridors are shown on Figure 2-30 and are described in the following paragraphs. DOE would need to obtain a 0.4-kilometer (0.25-mile)-wide right-of-way to construct a rail line and an associated access road. As shown in Figure 2-30, there are possible alignment variations, which are described further in Appendix J.

- *Caliente Rail Corridor Implementing Alternative.* The Caliente corridor originates at an existing siding to the Union Pacific mainline railroad near Caliente, Nevada (Figure 2-30). The corridor is 513 kilometers (319 miles) long from the Union Pacific line connection to the Yucca Mountain site.

- *Carlin Rail Corridor Implementing Alternative.* The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada (Figure 2-30). The Carlin and Caliente corridors converge near the northwest boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). Past this point, they are identical. The corridor is 520 kilometers (323 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

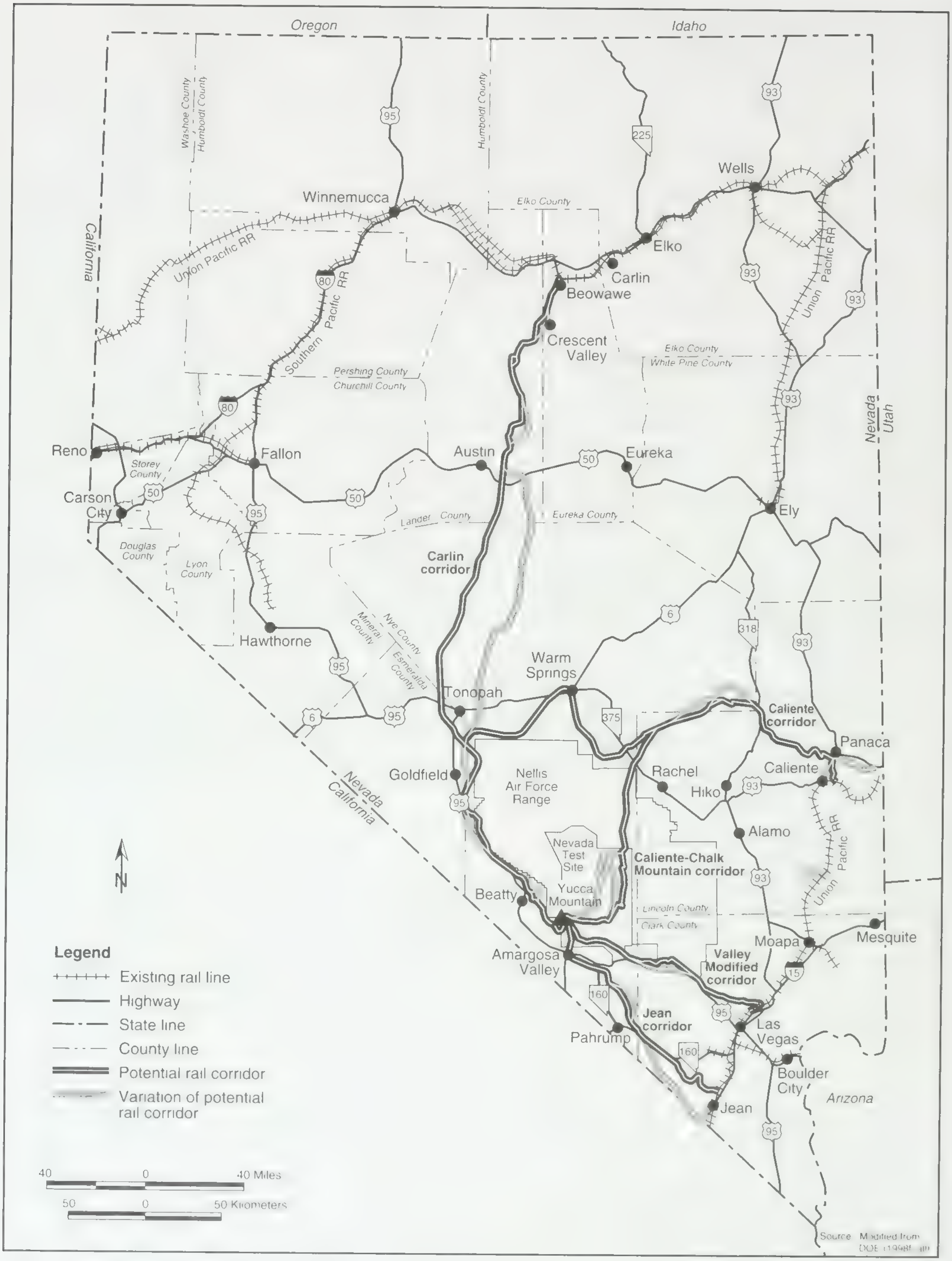


Figure 2-30. Potential Nevada rail routes to Yucca Mountatin.

- *Caliente-Chalk Mountain Rail Corridor Implementing Alternative.* The Caliente-Chalk Mountain corridor is identical to the Caliente corridor until it approaches the northern boundary of the Nellis Air Force Range. At that point the Caliente-Chalk Mountain corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site (Figure 2-30). The corridor is 345 kilometers (214 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain Site.

- *Jean Rail Corridor Implementing Alternative.* The Jean corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada (Figure 2-30). The corridor is 181 kilometers (112 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site.

- *Valley Modified Rail Corridor Implementing Alternative.* The Valley Modified corridor originates at an existing rail siding off the Union Pacific mainline railroad northeast of Las Vegas. The corridor is about 159 kilometers (98 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

2.1.3.3.2.1 Rail Line Construction. The selected rail line would be designed and built in compliance with Federal Railroad Administration safety standards. In addition, a service road along the rail line would be built and maintained. Rail line construction along any of the corridors would take an estimated 2.5 years. Construction would start after the selection of a route, completion of engineering studies, completion of the rail line design, and land acquisition.

Construction activities would include the development of construction support areas; construction of access roads to the rail line construction initiation points and to major structures to be built, such as bridges; and movement of equipment to the construction initiation points. The number and location of construction initiation points would be based on such variables as the route selected, the length of the line, the construction schedule, the number of contractors used for construction, the number of structures to be built, and the locations of existing access roads adjacent to the rail line.

> **RAILROAD CONSTRUCTION TERMS**
>
> **Borrow areas:** Areas outside the rail corridor where construction personnel could obtain materials to be used in the establishment of a stable platform (subgrade) for the rail track. Aggregate crushing operations could occur in these areas.
>
> **Spoils areas:** Areas outside the rail corridor for the deposition of excavated materials from rail line development.
>
> **Construction support areas:** Areas along the rail route that could be used as temporary residences for construction crews, material and equipment storage areas, and concrete production areas. Such camps probably would be for the construction of routes far from population centers.

The construction of a rail line would require the clearing and excavation of previously undisturbed lands in the corridor and the establishment of borrow and spoils areas outside the corridor. To establish a stable platform for the rail track, construction crews would excavate some areas and fill (add more soil to) others, as determined by terrain features. To the extent possible, material excavated from one area would be used in areas that required fill material. However, if the distance to an area requiring fill material was excessive, the excavated material would be disposed of in adjacent low areas, and a borrow area would be established adjacent to the area requiring fill material. Access roads to spoils and borrow areas would be built during the track platform construction work.

Typical heavy-duty construction equipment (front-end loaders, power shovels, and other diesel-powered support equipment) would be used for clearing and excavation work. Trucks would spray water along graded areas for dust control and soil compaction. The fill material used along the rail line to establish a stable platform for the track would be compacted to meet design requirements. Water could be shipped from other locations or obtained from wells drilled along the route.

Railroad track construction would consist of the placement of railbed material, ties, rail, and ballast (support and stabilizing materials for the rail ties) over the completed railbed platform. Other activities would include the following:

- Installation of at-grade crossings (which would require rerouting existing utility lines in some areas)
- Installation of fences along the rail line, if requested by other agencies (for example, the Bureau of Land Management or the Fish and Wildlife Service)
- Installation of the train control system (monitoring equipment, signals, communications equipment)
- Final grading of slopes, installation of rock-fall protection devices, replacement of topsoil, revegetation and installation of other permanent erosion control systems, and completion of the adjacent maintenance road

2.1.3.3.2.2 Rail Line Operations. Branch rail line operations from the junction with the main line to the proposed repository at Yucca Mountain would meet Federal Railroad Administration standards for maintenance, operations, and safety. Current plans for the branch rail line anticipate a train with two 3,000-horsepower, diesel-electric locomotives; from one to five railcars containing spent nuclear fuel and high-level radioactive waste; buffer cars; and escort cars.

The operational interface between the Union Pacific and the branch rail line would be determined by whether the waste was shipped to Nevada by dedicated rail service or by general freight rail service. With dedicated rail service to Nevada, the railcars would be transferred to the branch rail line and shipped immediately to the repository. With general freight service, the railcars carrying spent nuclear fuel or high-level radioactive waste could be parked on a side track (off the main rail line) at the connection point until a train could be assembled to travel to the repository site. A small secure railyard off the main rail line would be established for switching operations. Railcars with spent nuclear fuel or high-level radioactive waste would have to be moved within 48 hours in accordance with U.S. Department of Transportation regulations (49 CFR 174.14).

This EIS assumes there would be about four trains per week for shipments of spent nuclear fuel and high-level radioactive waste to the repository. In addition, the rail line would enable the transport of other material to the repository, including empty disposal containers, bulk concrete materials, steel, large equipment, and general building materials. The EIS assumes one train per week for this other material for a total of about five trains per week to the repository from about 2010 to 2033.

2.1.3.3.3 *Nevada Heavy-Haul Truck Scenario*

Under this scenario, rail shipments to Nevada would go to an intermodal transfer station where the shipping cask would transfer from the railcar to a heavy-haul truck. The heavy-haul truck would travel on existing roads to the repository. The following sections describe the implementing alternatives (the intermodal transfer station locations and associated highway routes for heavy-haul trucks) that the EIS analyzes.

2.1.3.3.3.1 Intermodal Transfer Stations. To enable intermodal transfers and heavy-haul shipments to the repository, an intermodal transfer station would be built and operated in Nevada. DOE is considering three potential locations for intermodal transfer operations: near Caliente, northeast of Las Vegas (Apex/Dry Lake), and southwest of Las Vegas (Sloan/Jean) (Figure 2-31). DOE has identified general areas at these three locations where it could build and operate an intermodal transfer station:

- *Caliente Intermodal Transfer Station Implementing Alternative.* The Caliente siting areas are south of Caliente in the Meadow Valley Wash. DOE has identified two possible areas along the west side of the wash.

- *Apex/Dry Lake Intermodal Transfer Station Implementing Alternative.* The potential areas northeast of Las Vegas are between the Union Pacific rail sidings at Dry Lake and Apex. Two large contiguous areas are available for intermodal transfer station siting near the Apex/Dry Lake sidings. The first area is directly adjacent to the Dry Lake siding along the west side of the Union Pacific line. The second area is on the east side of I-15 adjacent to the Union Pacific line and south of where the main Union Pacific line crosses I-15. Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary.

- *Sloan/Jean Intermodal Transfer Station Implementing Alternative.* The potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific rail sidings at Sloan and Jean. One area is on the west side of I-15, north of the Union Pacific rail underpass at I-15. The second is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15.

The intermodal transfer station would be a fenced area of about 250 meters (820 feet) by 250 meters and a rail siding that would be about 2 kilometers (1.2 miles) long (see Figure 2-32). The estimated total area occupied by the facility and support areas would be about 0.2 square kilometer (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail, and one on a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connection tracks to the existing Union Pacific line and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. Construction of an intermodal transfer station would take an estimated 1.5 years.

Intermodal transfer station operations would depend on whether the railcars that carried spent nuclear fuel and high-level radioactive waste arrived on dedicated or general freight trains. A dedicated train would enter the intermodal transfer station, passing the opened security gate and parking on a track for cask inspection. After inspection, the train would proceed to a loading and unloading track or a designated storage track (if the loading and unloading tracks were occupied).

General freight trains would switch from the main Union Pacific track to an existing or newly constructed passing track. The railcars carrying casks of spent nuclear fuel or high-level radioactive waste would be uncoupled from the freight train and switched to the intermodal transfer station track. The freight train would return to the main Union Pacific line and continue its trip. A railyard locomotive would move the cars containing the casks to the station.

The loading and unloading process would begin with the return of a heavy-haul truck from the repository. The empty cask returning from the repository would be lifted from the truck, loaded on an empty railcar, and secured. The gantry or mobile crane would then remove a loaded cask from another railcar and transfer it to the same truck, where it would be secured and inspected before shipment to the repository.

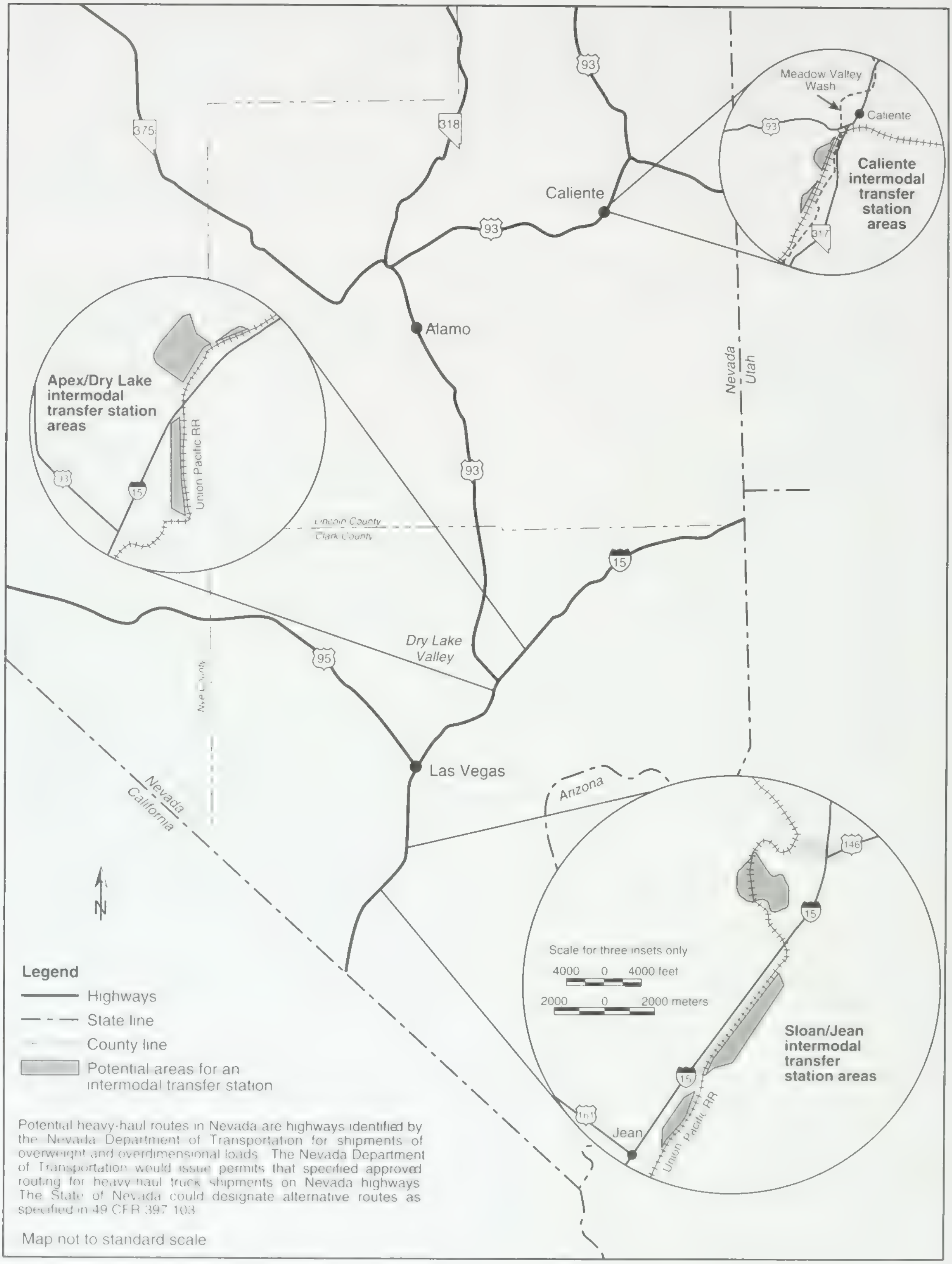


Figure 2-31. Potential intermodal transfer station locations.

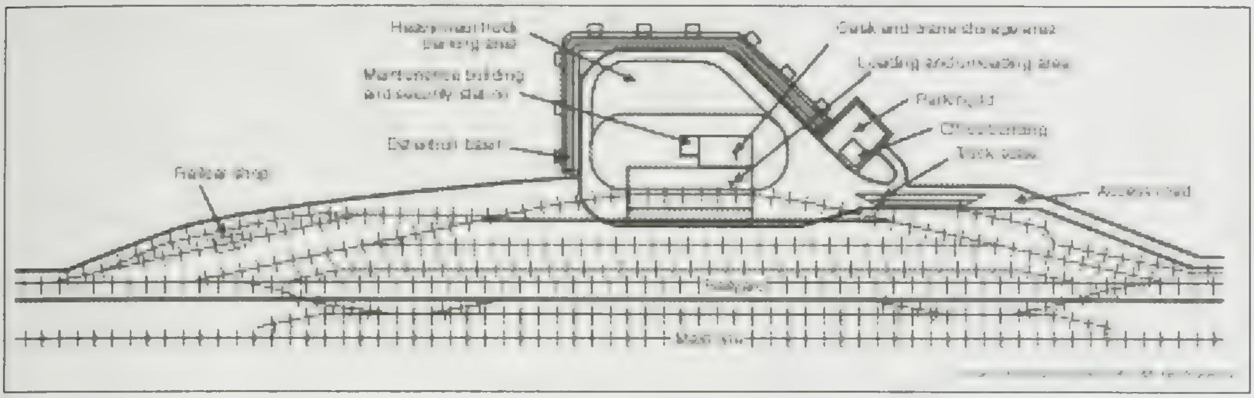


Figure 2-32. Conceptual diagram of intermodal transfer station layout.

The station would accept railcars as they arrived (24 hours a day, 7 days a week), but it would normally dispatch heavy-haul trucks during early morning daylight hours on weekdays, consistent with current Nevada heavy-haul shipment regulations.

At the completion of the 24 years of shipping, the intermodal transfer station would be decommissioned and, if possible, reused.

2.1.3.3.3.2 Highway Routes for Heavy-Haul Shipments. Figure 2-33 is an illustration of a heavy-haul truck that DOE could use to transport spent nuclear fuel and high-level radioactive waste to the repository. The heavy-haul truck would weigh about 91,000 kilograms (200,000 pounds) unloaded and would be up to 67 meters (220 feet) long. It would be custom-built for repository shipments. Average trip speeds would be 32 to 48 kilometers (20 to 30 miles) per hour.

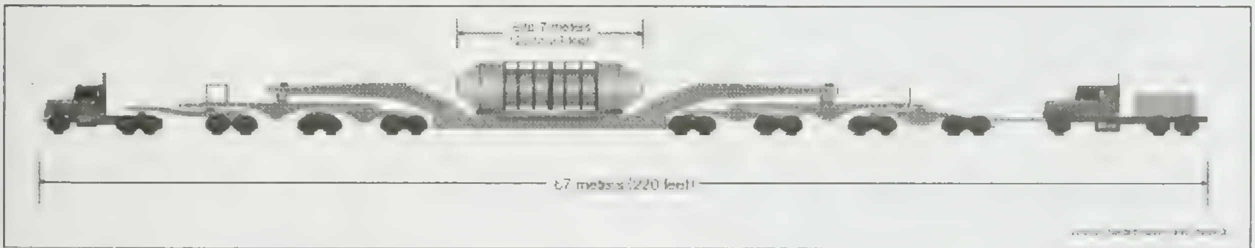


Figure 2-33. Artist's conception of a heavy-haul truck carrying a rail shipping cask.

Heavy-haul truck shipments from an intermodal transfer station to the repository would comply with U.S. Department of Transportation requirements for shipments of highway route-controlled quantities of radioactive materials (49 CFR Part 177) and with State of Nevada permit requirements for heavy-haul shipments. Nevada permits heavy-haul shipments on Monday through Friday (excluding holidays) but only in daylight hours.

Road upgrades for candidate routes, if necessary, would involve four kinds of construction activities: (1) widening the shoulders and constructing turnouts and truck lanes, (2) upgrading intersections that are inadequate for heavy-haul truck traffic, (3) increasing the asphalt thickness (overlay) of some sections, and (4) upgrading engineered structures such as culverts and bridges. The overlay work would include upgrades needed to remove frost restrictions from some road sections.

Shoulder widening and the construction of turnouts and truck lanes would occur as needed along the side of the existing pavement. Shoulders would be widened from 0.33 or 0.66 meter (1 or 2 feet) to 1.2 meters (4 feet). Widening would build the existing shoulder up to pavement height. Truck lanes would be built on roadways with grades exceeding 4 percent. Turnout lanes would be built approximately every 8 to 32

kilometers (5 to 20 miles) depending on projected traffic. The truck lanes and turnouts would require land clearing and soil excavation or fill to establish the roadway. Culverts under the roadway would be lengthened. Most borrow material for construction could come from existing Nevada Department of Transportation borrow areas, if the State agreed. Asphalt could be produced at a portable plant in the borrow areas. Appendix J contains descriptions of the specific highway improvements for the five routes.

The following paragraphs describe the potential highway routes for heavy-haul trucks DOE is considering for the intermodal transfer station location and unique operational considerations for each route.

- *Caliente Intermodal Transfer Station Highway Routes.* Heavy-haul trucks leaving the Caliente intermodal transfer station could travel on one of three potential routes: (1) Caliente, (2) Caliente-Chalk Mountain, and (3) Caliente-Las Vegas (see Figure 2-34).

  The Caliente route would be approximately 533 kilometers (331 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. Highway 6. The trucks would continue on U.S. 6 to the intersection with U.S. 95 in Tonopah, then into Beatty on U.S. 95, where an alternate truck route would be built because the existing intersection is too constricted to allow a turn. Heavy-haul trucks would then travel south on U.S. 95 to the Lathrop Wells Road exit, which accesses the Yucca Mountain site. Because of the estimated travel time associated with the Caliente route and the restriction on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable these vehicles to park overnight. This parking area would be near the U.S. 6 and U.S. 95 interchange at Tonopah.

  The Caliente-Chalk Mountain route would be approximately 282 kilometers (175 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, on State Route 375 to Rachel, and head south through the Nellis Air Force Range to the Nevada Test Site.

  The Caliente-Las Vegas route would be approximately 377 kilometers (234 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15, northeast of Las Vegas. The trucks would travel south on I-15 to the exit for the proposed northern Las Vegas Beltway, then would travel west on the beltway. They would leave the beltway at U.S. 95, and head north on U.S. 95 to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

- *Apex/Dry Lake Intermodal Transfer Station Highway Route.* Heavy-haul trucks would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway, and would travel west on the beltway. The trucks would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Nevada Test Site. They would then travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. This route is about 183 kilometers (114 miles) long (see Figure 2-34).

- *Sloan/Jean Intermodal Transfer Station Highway Route.* Heavy-haul trucks leaving a Sloan/Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel to the Nevada Test Site. They would then travel on Jackass Flats Road to the Yucca Mountain site. This route would be approximately 188 kilometers (117 miles) long (see Figure 2-34).

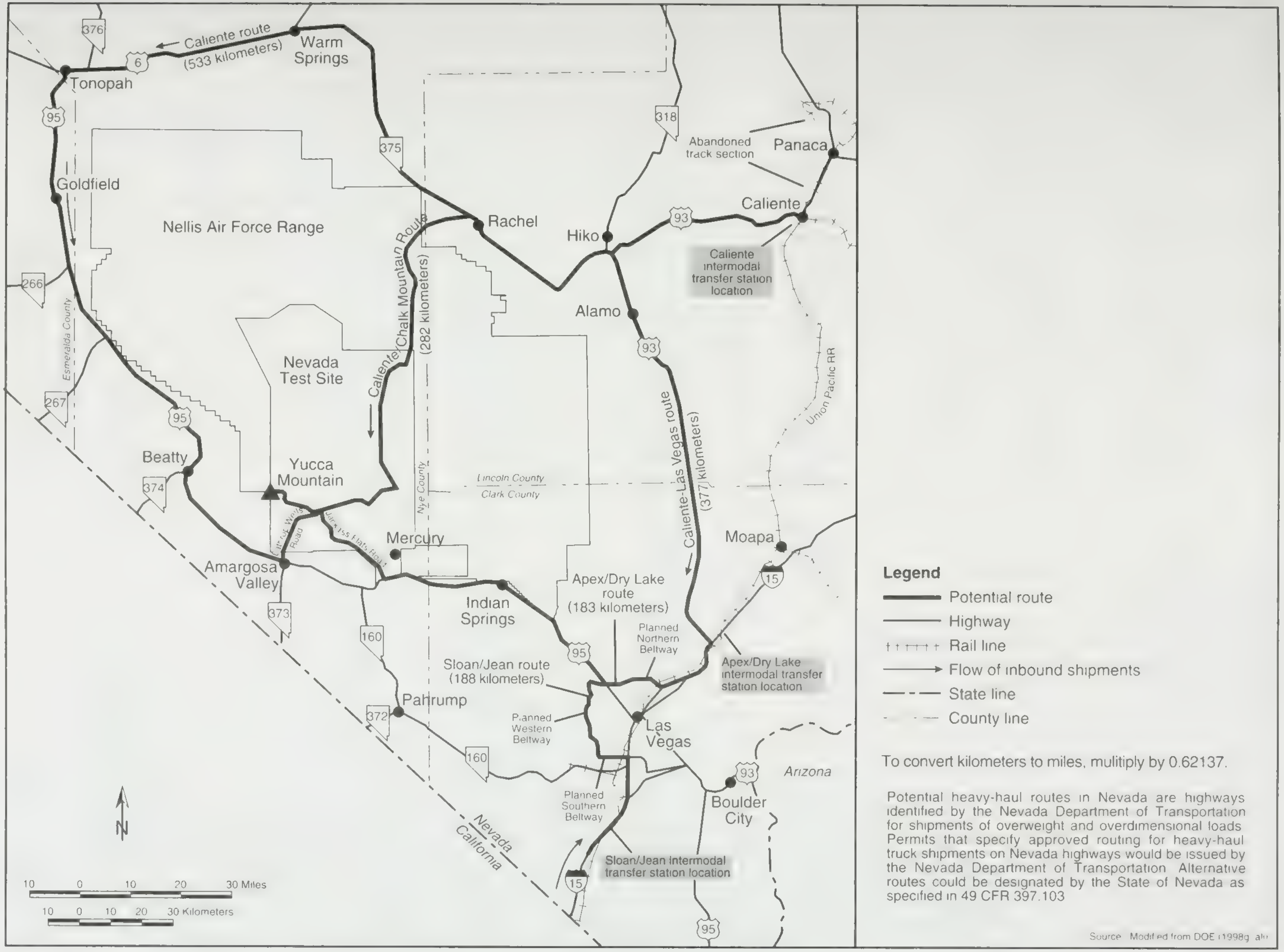


Figure 2-34. Potential routes in Nevada for heavy-haul trucks.

2.1.3.4 Shipping Cask Manufacturing, Maintenance, and Disposal

To transport spent nuclear fuel and high-level radioactive waste to the repository, DOE would use existing or new shipping casks that met Nuclear Regulatory Commission regulations (10 CFR Part 71). One or more qualified companies that provide specialized metal structures, tanks, and other heavy equipment would manufacture new shipping casks. The number and type of shipping casks required would depend on the predominant mode of transportation.

DOE would remove casks from service periodically for maintenance and inspection. These activities would occur at a cask maintenance facility(s) where cask functions and components would be checked and inspected in compliance with Nuclear Regulatory Commission requirements and preventive maintenance procedures. The major operations involved in cask maintenance would include decontamination, replacement of limited-life components such as O-rings, and verification of radiation shielding integrity, structural integrity, and heat transfer efficiency.

The large number of repository shipments would require new facilities for cask maintenance. DOE has not decided where in the United States it would locate a cask maintenance facility(s), but this EIS assumes that such a facility would be at the repository inside the Restricted Area at the North Portal on approximately 0.01 square kilometer (2.5 acres). Minor cask maintenance activities could occur at commercial or DOE sites.

2.1.4 ALTERNATIVE DESIGN CONCEPTS AND DESIGN FEATURES

The EIS analyzed thermal load and packaging scenarios to identify the range of potential short- and long-term impacts of a repository at Yucca Mountain. This analysis used conceptual designs, which is typical for an EIS. However, the level of design is insufficient to meet information needs for a License Application to the Nuclear Regulatory Commission. Therefore, the repository design will continue to evolve through the submittal of the License Application.

As part of this evolving design process, DOE is evaluating various design features and alternatives. The purpose of the evaluation is to determine if these features and alternatives would reduce uncertainties in the long-term performance of the repository, reduce costs, or improve operations. Other construction materials could be evaluated in the future. The License Application Design Selection project is considering a variety of design alternatives and features, as described in Appendix E. In addition, DOE has made preliminary identification of five combinations of design features and alternatives, called Enhanced Design Alternatives, as part of this process (Table 2-4). The EIS analysis categorized the design features and alternatives into three groups, based on their primary function, which are intended to:

- Limit the release and transport of radionuclides
- Control the thermal/moisture environment in the repository
- Support operational and cost considerations

The following sections summarize the design approaches for the three groups DOE is considering within the scope of the design features and alternatives.

2.1.4.1 Design Features and Alternatives To Limit Release and Transport of Radionuclides

The features related to improving the barriers that limit the release and transport of radioactive material focus on two areas of the design. Some of the features focus on improvements in the long-term integrity

Table 2-4. Design features and alternatives used to form Enhanced Design Alternatives.

Category	Enhanced Design Alternative				
	I	II	III	IV	V
Barriers to limit release and transport of radionuclides					
Drip shields	X[a]	X	X	X	X
Backfill to protect waste package and drip shield from rockfall		X		X	
Waste package corrosion-resistant barrier	X	X	X		X
Additives and fillers				X	
Ground support options			X		
Repository design to control thermal/moisture environment					
Low thermal alternative evaluation	X	X			
Aging and blending of waste	X	X			X
Continuous postclosure ventilation	X	X	X	X	X
Drift diameter	X				
Waste package spacing and drift spacing	X	X	X	X	X
Higher thermal load					X
Repository designs to support operational and cost considerations					
Enhanced access design	X	X	X	X	X
Timing of repository closure	X	X	X	X	X
Maintenance of underground design features and ground support			X		

a. X specifies what is used in each Enhanced Design Alternative.

of the waste packages; others focus on limiting the transport of radioactive material released from a waste package to the environment. Examples of designs include the following:

- Designs to improve the long-term integrity of waste packages, including coating the package with a ceramic or using multiple types of corrosion-resistant materials, which should directly reduce waste package failure due to corrosion.

- Designs to reduce the potential of structural damage to waste packages from rockfall, such as backfilling the drifts or providing mechanical support to the drift wall (concrete or steel liner).

- Designs to limit the transport of radionuclides, including additives and fillers to the waste packages or getters under the waste packages; these substances would capture radionuclides chemically to limit transport.

Some features provide the potential to limit both the release and transport of radionuclides, and to modify the temperature environment. For instance, backfill could protect against the release and transport of contaminants by capturing corrosive salts in the water and retarding flow and by increasing the emplacement drift temperature to decrease the relative humidity. For convenience of presentation, each feature is listed in only one category.

2.1.4.2 Design Features and Alternatives To Control the Thermal/Moisture Environment in the Repository

Potentially the most effective repository design would provide an environment in the emplacement drifts that would accommodate the heat discharge from the waste packages, maintain the materials and contents of the packages at low temperatures, and maintain low ambient moisture. Several alternatives and features focus on these goals. An example of a design to control the repository drift environment would be continuous postclosure ventilation of the drifts to provide both heat and moisture removal.

Many designs use an integrated approach to control the drift environment. The high thermal load designs, for example, provide ambient temperatures above 100°C (212°F) through portions of the repository so moisture would vaporize and disperse. Designs involving the diameter and spacing of drifts and the loading of waste packages consider similar integrated effects to control the heat load. Some designs focus only on moisture control, such as those that involve surface modifications directly above the repository to retard or eliminate any infiltration of moisture.

2.1.4.3 Design Features and Alternatives To Support Operational and Cost Considerations

In general, these design features and alternatives focus on repository operation and cost, so they would not usually affect long-term (postclosure) performance but could have short-term (preclosure) impacts. Designs to enhance access to the drifts and to facilitate performance monitoring incorporate approaches that would reduce occupational exposure. Modular design and phased construction would result in slightly increased short-term impacts but would accommodate incremental funding of repository construction.

The final design of the repository is likely to evolve from the current design (as described in Section 2.1 and analyzed in this EIS), combinations of the design features and alternatives, and other design concepts that evolve from the DOE License Application Design Selection process (that is, Enhanced Design Alternatives). The identification and evolution of the features and alternatives was underway as DOE was preparing the Draft EIS. The evolution of the repository design is likely to incorporate some of the features and alternatives discussed in this section and Appendix E. After incorporating modifications in the design, DOE will evaluate the environmental impacts associated with the updated design in the Final EIS.

The design features and alternatives are functionally equivalent to potential mitigation measures because they have the potential to improve long-term (postclosure) performance (that is, they would reduce risk), reduce operational impacts, or reduce costs. Chapter 9 summarizes the mitigation aspects of these design features and alternatives and Appendix E describes them more fully. However, there are tradeoffs associated with many of these features and alternatives that could have negative short-term (preclosure) or long-term impacts that could be greater than the impacts associated with the basic design under the thermal load and packaging scenarios evaluated as part of the Proposed Action. Appendix E contains qualitative descriptions of the features and alternatives, including the reasons for their consideration (potential benefits) and potential negative environmental considerations.

2.1.5 ESTIMATED COSTS ASSOCIATED WITH THE PROPOSED ACTION

DOE has estimated the total cost of the Proposed Action to construct, operate and monitor, and close a geologic repository at Yucca Mountain, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository (TRW 1999e, all). The estimate is based on acceptance and disposal of about 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). Table 2-5 lists the estimated costs. The costs would total about $29 billion. This is representative and would vary

Table 2-5. Proposed Action costs.[a,b]

Description	Costs
Monitored geologic repository	$18.7
Waste acceptance, storage, and transportation	4.5
Nevada transportation	0.8
Program integration	2.1
Institutional	2.7
Total	**$28.8**

a. Source: TRW (1999e, all).

b. Adjusted to constant 1998 dollars, in billions.

somewhat, depending on the thermal load, packaging, and transportation scenarios and on the Nevada transportation implementing alternative selected.

2.2 No-Action Alternative

This section describes the No-Action Alternative, which provides a baseline for comparison with the Proposed Action. Under the No-Action Alternative and consistent with the Nuclear Waste Policy Act, as amended [Section 113(c)(3) (the EIS refers to the amended Act as the NWPA)], DOE would end site characterization activities at Yucca Mountain and undertake site reclamation to mitigate adverse environmental impacts from characterization activities. Commercial nuclear power utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States (see Figure 2-35).

Under the NWPA, if DOE decided not to proceed with the development of a repository at Yucca Mountain, it would prepare a report to Congress with its recommendations for further action to ensure the safe permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Furthermore, DOE intends to comply with the terms of existing consent orders and compliance agreements regarding the management of spent nuclear fuel and high-level radioactive waste. However, the future course that Congress, DOE, and the commercial nuclear power utilities would take if Yucca Mountain were not recommended as a repository remains uncertain. A number of possibilities could be pursued, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository (Chapter 1 discusses alternative sites previously selected by DOE for technical study); development of new technologies (for example, transmutation); or reconsideration of other disposal alternatives to deep geologic disposal (Section 2.3.1 discusses other disposal options previously evaluated by DOE). The environmental considerations related to continued storage at current locations or at one or more centralized location(s) have been analyzed in other contexts for both commercial and DOE spent nuclear fuel and high-level radioactive waste in several documents (see Chapter 7, Table 7-1 for a description of representative studies). Under any future course that would include continued storage, both commercial and DOE sites would have an obligation to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment.

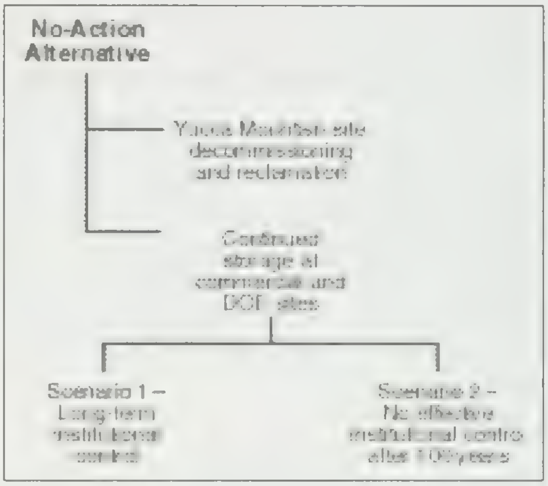


Figure 2-35. No-Action Alternative activities and analytical scenarios.

In light of the uncertainties described above, DOE decided to illustrate one set of possibilities by focusing its analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Long-term storage of spent nuclear fuel and high-level radioactive waste at the current storage sites with effective institutional control for at least 10,000 years (Scenario 1)

- Long-term storage at the current storage sites with no effective institutional control after approximately 100 years (Scenario 2)

DOE recognizes that neither of these scenarios is likely to occur in the event there is a decision not to develop a repository at Yucca Mountain. However, these two scenarios were chosen for analysis because they provide a baseline for comparison to the impacts from the Proposed Action and they reflect a range of the impacts that could occur. Scenario 1, which includes an analysis of impacts under effective institutional controls for at least 10,000 years, is consistent with the portion of the analysis of the Proposed Action that includes an analysis of effective institutional controls for the first 100 years after closure. Scenario 2, in which the analyses do not consider institutional controls after approximately 100 years, is consistent with the portion of the analysis of the Proposed Action in which long-term performance after 100 years also does not include institutional controls.

The following sections describe expected Yucca Mountain site decommissioning and reclamation activities (Section 2.2.1), and further describe the scenarios for continued spent nuclear fuel and high-level radioactive waste management at the commercial and DOE sites (Section 2.2.2). Chapter 7 describes the potential environmental impacts of the No-Action Alternative.

2.2.1 YUCCA MOUNTAIN SITE DECOMMISSIONING AND RECLAMATION

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain and decommissioning and reclamation would begin as soon as practicable and could take several years to complete. Decommissioning and reclamation would include removing or shutting down surface and subsurface facilities, and restoring lands disturbed during site characterization.

> **INSTITUTIONAL CONTROL**
>
> Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

Portable and prefabricated buildings would be emptied of their contents, dismantled, and removed from the site. Other facilities could be shut down without being removed from the site. DOE would remove and salvage such equipment as electric generators and tunneling, ventilation, meteorological, and communications equipment. Foundations and similar materials would remain in place.

DOE would remove equipment and materials from the underground drifts and test rooms. Horizontal and vertical drill holes extending from the subsurface would be sealed. Subsurface drifts and rooms would not be backfilled, but would be left with the concrete inverts in place. The North and South Portals would be gated to prohibit entry to the subsurface.

Excavated rock piles would be stabilized. Topsoil previously removed from the excavated rock pile area and stored in a stockpile would be returned and the areas would be revegetated. Areas disturbed by surface studies (drilling, trenching, fault mapping) or used during site characterization (borrow areas, laydown pads, etc.) would be restored. Fluid impoundments (mud pits, evaporation ponds) would be backfilled or capped as appropriate and reclaimed. Access roads throughout the site (paved or graveled) and parking areas would be left in place and would not be restored.

2.2.2 CONTINUED STORAGE OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT COMMERCIAL AND DOE SITES

Under the No-Action Alternative, spent nuclear fuel and high-level radioactive waste would be managed at the 72 commercial and 5 DOE sites (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, Fort St. Vrain, and the West Valley Demonstration Project) (see Figure 1-1). The No-Action Alternative assumes that the spent nuclear fuel and high-level

radioactive waste would be treated, packaged, and stored. The amount of spent nuclear fuel and high-level radioactive waste considered in this analysis is the same as that in the Proposed Action—70,000 MTHM, including 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). This EIS assumes that the No-Action Alternative would start in 2002.

2.2.2.1 Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection to the environment from spent nuclear fuel and high-level radioactive waste. Because specific designs have not been identified for most locations, DOE selected a representative range of commercial and DOE designs for analysis as described in the following paragraphs.

Spent Nuclear Fuel Storage Facilities

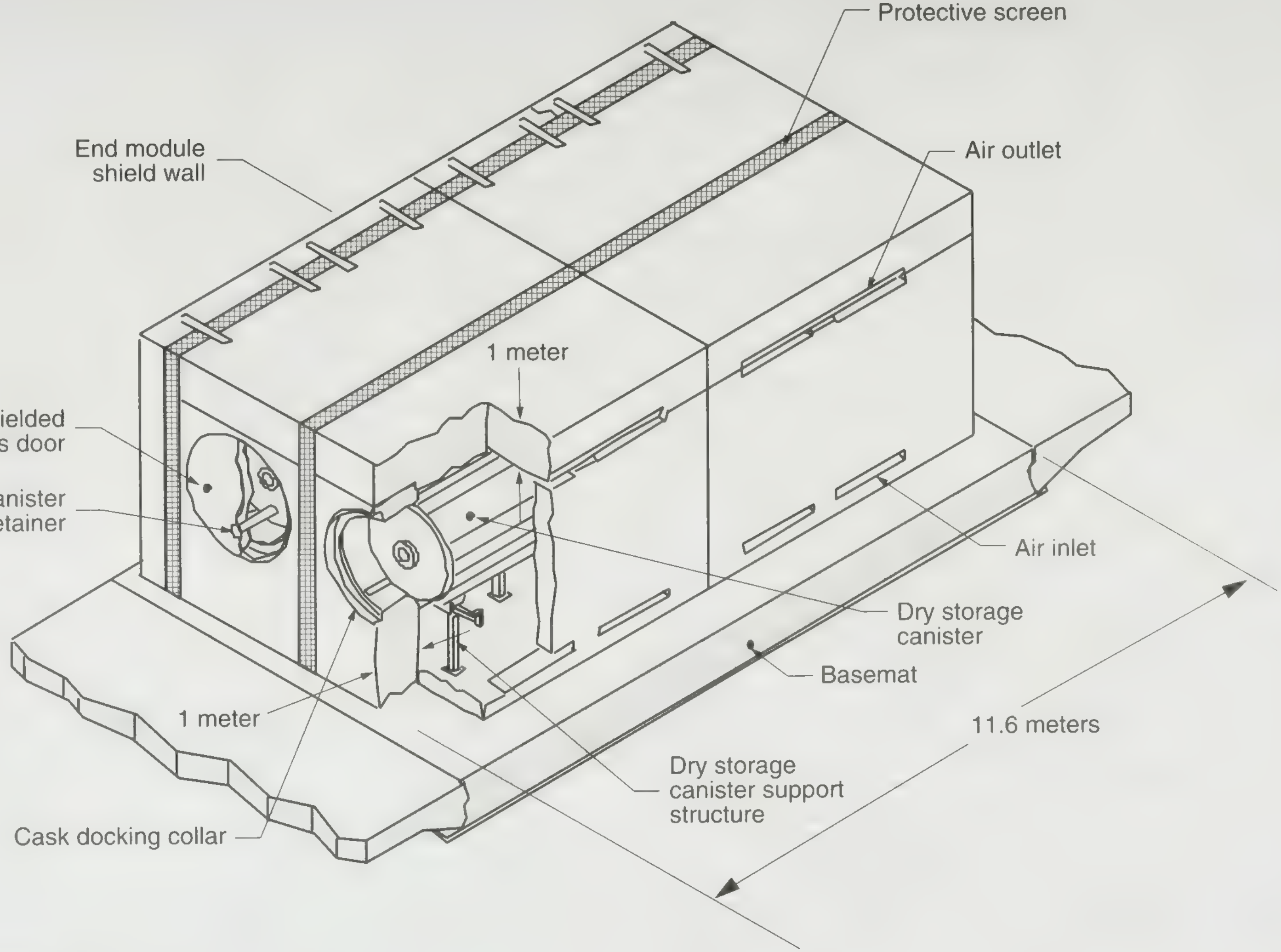
Most commercial nuclear utilities currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor site. Some utilities have built *independent spent fuel storage installations* in which they store spent nuclear fuel dry, above ground, in metal casks or in weld-sealed canisters inside reinforced concrete storage modules. Some utilities are planning to build independent spent fuel storage installations so they can proceed with decommissioning their nuclear plants and terminating their operating licenses (for example, the Rancho Seco and Trojan plants). Because utilities could elect to continue operations until their fuel pools are full and then cease operations, the EIS analysis originally considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is the preferred option for long-term spent nuclear fuel storage at commercial sites for the following reasons (NRC 1996, pages 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, amounts of low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be in dry storage at independent spent fuel storage installations at existing locations. This includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Figure 2-36 shows a photograph of the independent spent fuel storage installation at the Calvert Cliffs commercial nuclear site. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluated the impacts of storing all commercial and most DOE spent nuclear fuel in horizontal concrete storage modules (see Figure 2-37) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that both pressurized-water reactor and boiling-water reactor spent nuclear fuel would have been loaded into a dry storage canister that would be placed inside the concrete storage module. Figure 2-38 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were properly maintained. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. The concrete storage module would also provide protection from damage from such occurrences as aircraft crashes, earthquakes, and tornadoes.

Figure 2-36. Calvert Cliffs independent spent fuel storage installation and reactors.

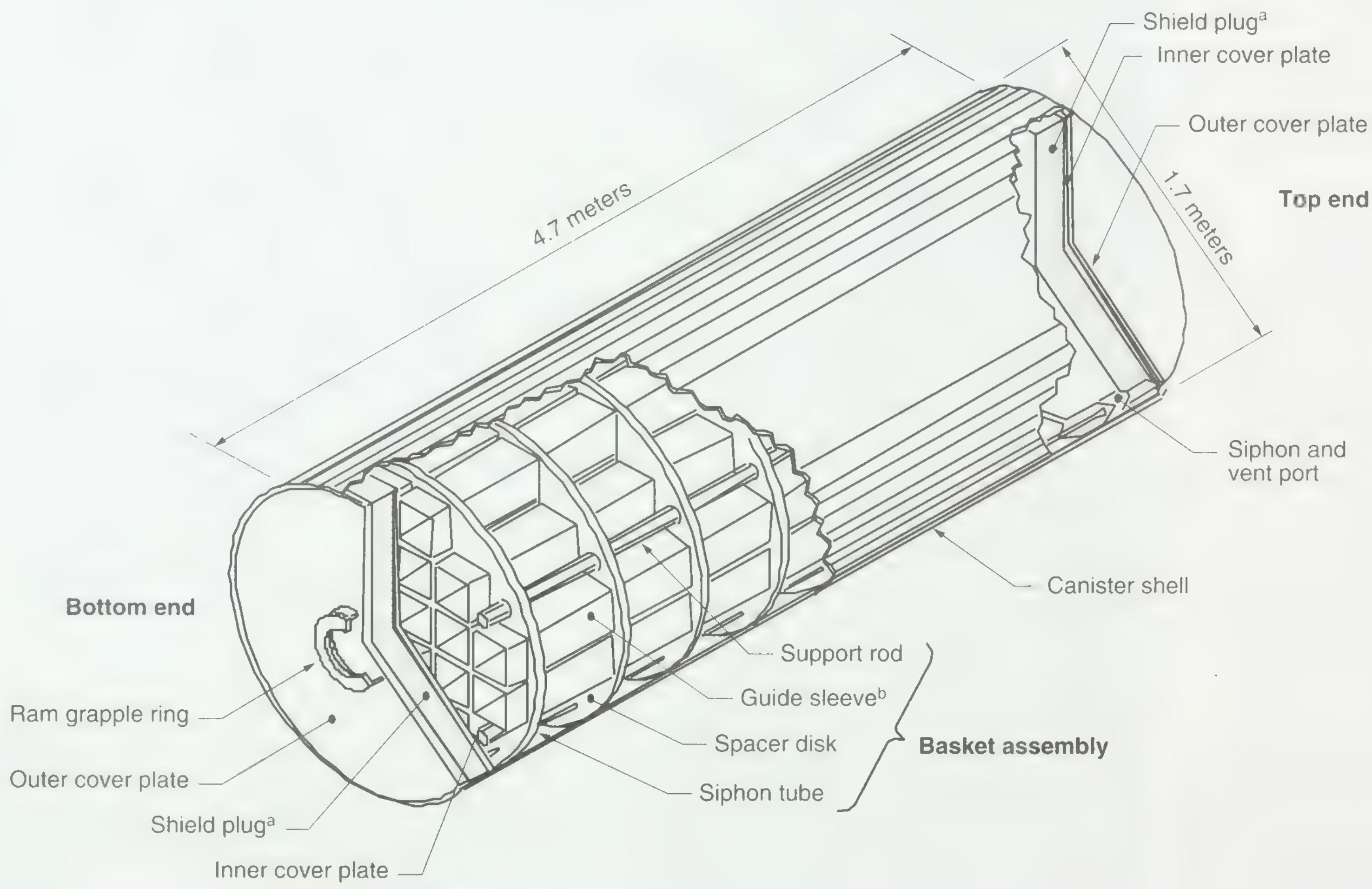


To convert meters to feet, multiply by 3.2808.

Note: Arrangement shown is a row of two storage modules with two canisters in each module.

Source: Modified from Poe (1998a, page 1-2)

Figure 2-37. Spent nuclear fuel concrete storage module.



All materials 304 stainless steel except as noted.

a. Shield plug would be lead.

b. Borated neutron absorber plate for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from Poe (1998a, page 1-5)

Figure 2-38. Spent nuclear fuel dry storage canister.

This analysis assumed that DOE spent nuclear fuel at the Savannah River Site, Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain would be stored dry, above ground in stainless-steel canisters inside concrete casks. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial nuclear sites.

The analysis assumed that DOE spent nuclear fuel at Hanford would be stored dry in below-grade storage facilities. The Hanford N-Reactor fuel would be stored in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. Storage tubes of carbon steel would be installed vertically in the vaults. Each storage tube, which would be able to accommodate two spent nuclear fuel canisters, would be closed and sealed with a shield plug. The vaults would be covered by a structural steel shelter.

High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that high-level radioactive waste would be stored in a below-grade solidified high-level radioactive waste storage facility (Figure 2-39). At the West Valley Demonstration Project, it was assumed that DOE would use a dry storage system similar to a commercial spent nuclear fuel storage installation for high-level radioactive waste storage.

The high-level radioactive waste storage facility has four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally stepped steel plates that direct most of the ventilation air through the storage cavities.

The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment as long as the facilities were maintained. Radiation shielding would be provided by the surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The heat of radioactive decay would be removed from around the canisters by the facility's forced air exhaust system. The exhaust air could be filtered with high-efficiency particulate air filters before it was discharged to the atmosphere through a stack, or natural convection cooling could be used with no filter. The oversize diameter of the pipe storage cavities would allow air passage around each cavity.

2.2.2.2 No-Action Scenario 1

In No-Action Scenario 1, DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-grade dry storage facilities at five sites around the country. Commercial utilities would continue to manage their spent nuclear fuel at 72 sites. The commercial and DOE sites would remain under effective institutional control for at least 10,000 years. Under institutional control, these facilities would be maintained to ensure that workers and the public were protected adequately in accordance with current Federal regulations (10 CFR Parts 20 and 835) and the requirements in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.* DOE based the 10,000-year analysis period on the generally applicable Environmental Protection Agency regulation for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), even though the regulation would not apply to disposal at Yucca Mountain.

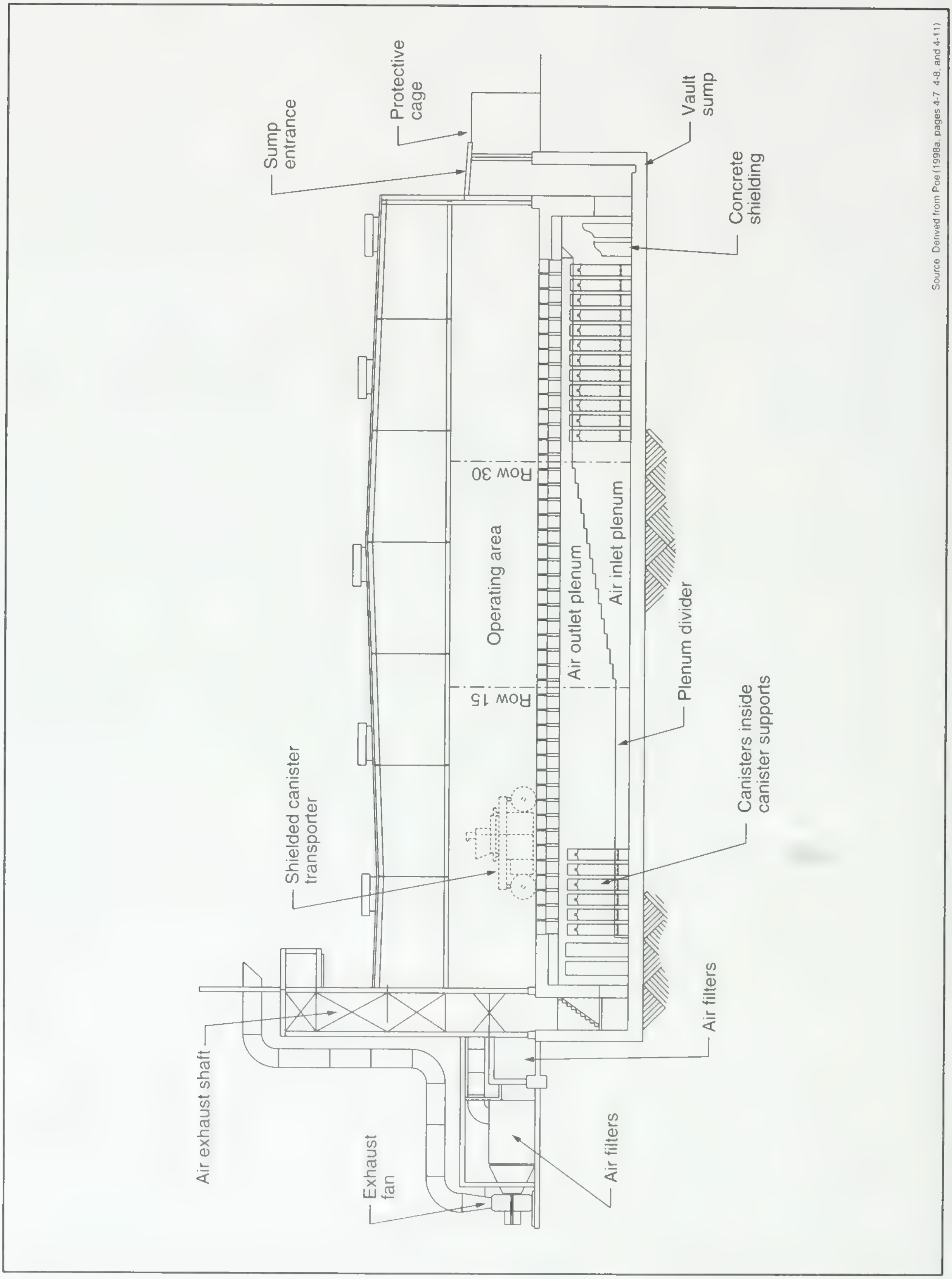


Figure 2-39. Conceptual design for solidified high-level radioactive waste storage facility.

Under Scenario 1, the storage facilities would be completely replaced every 100 years. They would undergo one major repair during the first 100 years, because this scenario assumes that the design of the first storage facilities at a site would include a facility life of less than 100 years. The 100-year lifespan of future storage facilities is based on analysis of concrete degradation and failure in regions throughout the United States (Poe 1998a, all). The facility replacement period of 100 years represents the assumed useful lifetime of the structures. Replacement facilities would be built on land adjacent to the existing facilities. After the spent nuclear fuel and high-level radioactive waste had been transferred to the replacement facility, the older facility would be demolished and the land prepared for the next replacement facility, thereby minimizing land-use impacts. The top portion of Figure 2-40 shows the conceptual timeline for activities at the storage facilities for Scenario 1. Only the relative periods shown on this figure, not the exact dates, are important to the analysis.

2.2.2.3 No-Action Scenario 2

In No-Action Scenario 2, spent nuclear fuel and high-level radioactive waste would remain in dry storage at commercial and DOE sites and would be under effective institutional control for approximately 100 years (the same as Scenario 1). Beyond that time, the scenario assumes no effective institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that the radioactive materials in them could eventually be released to the environment. DOE based the choice of 100 years on a review of generally applicable Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191, Subpart B), Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and a National Research Council report on standards for the proposed Yucca Mountain Repository that generally discounts the consideration of institutional control for longer periods in performance assessments for geologic repositories (National Research Council 1995, Chapter 4). The lower portion of Figure 2-40 shows the conceptual timeline for activities at the storage facilities for Scenario 2.

2.2.3 NO-ACTION ALTERNATIVE COSTS

The total estimated cost of the No-Action Alternative includes costs for the decommissioning and reclamation of the Yucca Mountain site, and for the storage of spent nuclear fuel at 72 commercial sites (63,000 MTHM), storage of DOE spent nuclear fuel (2,333 MTHM) at 4 sites (there would be no spent nuclear fuel at the West Valley Demonstration Project), and storage of solidified high-level radioactive waste (8,315 canisters) at 4 sites (there is no high-level radioactive waste at Fort St. Vrain). As listed in Table 2-6, the estimated cost of both Scenarios 1 and 2 for the first 100 years ranges from $51.5 billion to $56.7 billion, depending on whether the dry storage canisters have to be replaced every 100 years. The estimated cost for the remaining 9,900 years of Scenario 1 ranges from $480 million to $529 million per year. There are no costs for Scenario 2 after the first 100 years because the scenario assumes no effective institutional control.

2.3 Alternatives Considered but Eliminated from Detailed Study

This section addresses alternatives that DOE considered but eliminated from detailed study in this EIS. These include alternatives that the NWPA states this EIS need not consider (Section 2.3.1); design alternatives that DOE considered but eliminated during the evolution of the repository design analyzed in this EIS (Section 2.3.2); and alternative rail corridors and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated during the transportation studies that identified the 10 Nevada implementing rail and intermodal alternatives analyzed in this EIS (Section 2.3.3).

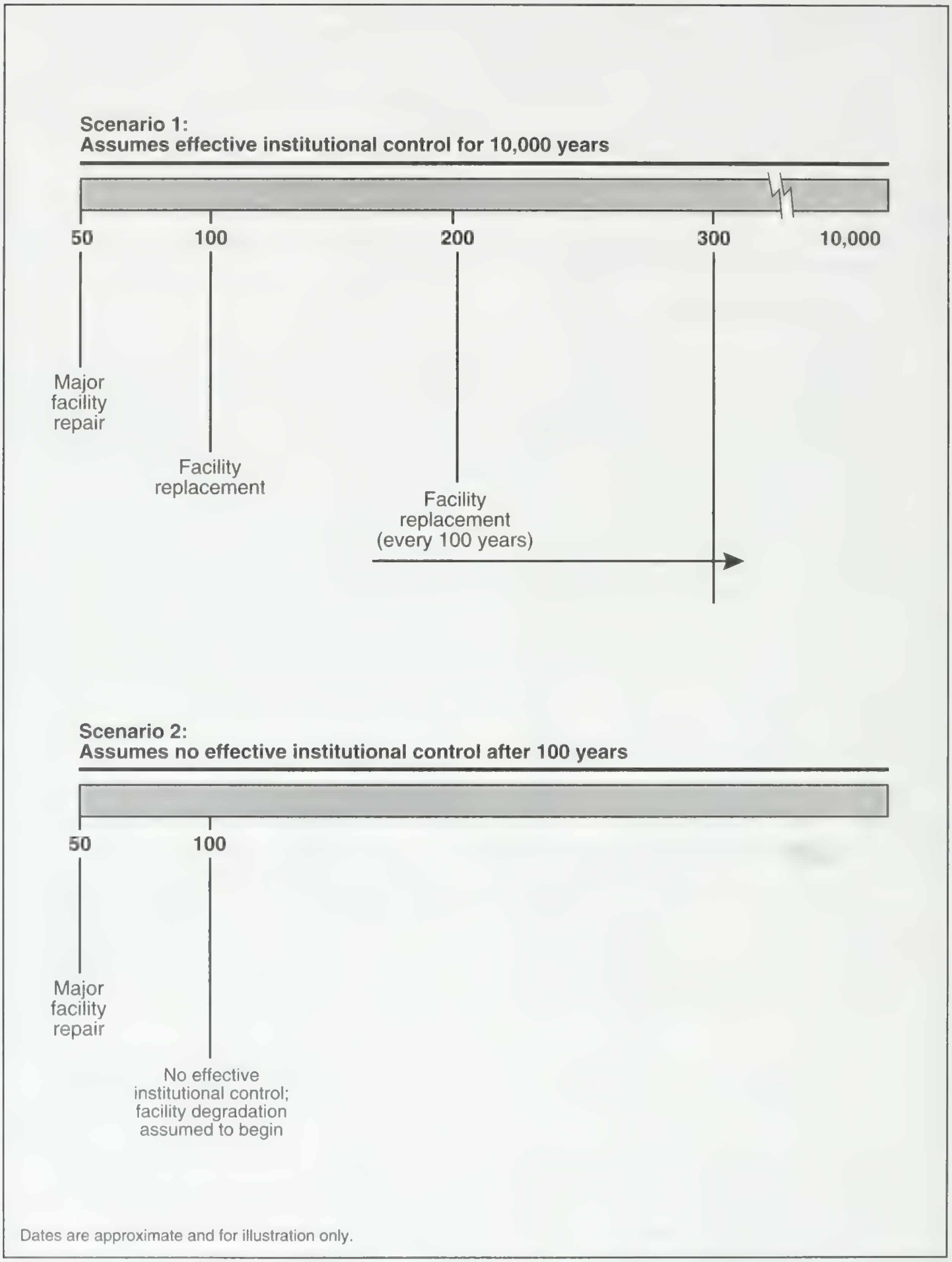


Figure 2-40. Facility timeline assumptions for No-Action Scenarios 1 and 2.

Table 2-6. No-Action Alternative life-cycle costs (in billions of 1998 dollars).[a]

Factor	First 100 years	Remaining 9,900 years (per year)	
	Scenarios 1 and 2[b]	Scenario 1[b,c]	Scenario 2[d]
72 commercial sites (63,000 MTHM)	$40.3 - 45.5	$0.376 - 0.425	$0
DOE spent nuclear fuel storage sites (2,333 MTHM)	7.4	0.069	0
High-level radioactive waste storage sites (8,315 canisters)	3.8	0.035	0
Decommissioning and reclamation of the Yucca Mountain site	(e)	NA[f]	0
Totals	**$51.5 - 56.7**	**$0.480 - 0.529**	**$0**

a. Source: TRW (1999e, all).
b. The range of costs for commercial sites is based on the assumption that the spent nuclear fuel would either be placed in dry storage canisters that would not need to be replaced over the 10,000-year period (low cost) or would have to be placed in new dry storage canisters every 100 years (high cost).
c. Stewardship costs are expressed in average annual disbursement costs (constant year 1998 dollars) only.
d. Costs are not applicable.
e. The costs for decommissioning and reclamation of the Yucca Mountain site would contribute less than 0.1 percent to the total life-cycle cost of continued storage.
f. NA = not applicable.

2.3.1 ALTERNATIVES ADDRESSED UNDER THE NUCLEAR WASTE POLICY ACT

The NWPA states that, with respect to the requirements imposed by the National Environmental Policy Act, compliance with the procedures and requirements of the NWPA shall be deemed adequate consideration of the need for a repository, the time of the initial availability of a repository, and all alternatives to the isolation of spent nuclear fuel and high-level radioactive waste in a repository [Section 114(f)(2)]. The geologic disposal of radioactive waste has been the focus of scientific research for more than 40 years. Starting in the 1950s, the Atomic Energy Commission and the Energy Research and Development Administration (both predecessor agencies to DOE) investigated different geologic formations as potential hosts for repositories and considered different disposal concepts, including deep-seabed disposal, disposal in the polar ice sheets, and rocketing waste into the sun. After extensive discussion of the options in an EIS (DOE 1980, all), DOE decided in 1981 to pursue disposal in an underground mined geologic repository (46 *FR* 26677, May 14, 1981). A panel of the National Academy of Sciences noted in 1990 that there is a worldwide scientific consensus that deep geologic disposal, the approach being followed by the United States, is the best option for disposing of high-level radioactive waste (National Research Council 1990, all).

Chapter 1 of this EIS summarizes the process that led to the 1987 amendments to the Nuclear Waste Policy Act of 1982, in which Congress directed DOE to study only Yucca Mountain to determine if it is suitable for a repository. Consistent with this approach, the NWPA states that, for purposes of complying with the requirements of the National Environmental Policy Act, DOE need not consider alternative sites to Yucca Mountain for the repository [Section 114(f)(3)].

Under the Proposed Action, this EIS does not consider alternatives for the emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement in the first repository of a quantity of spent nuclear fuel containing more than 70,000 MTHM or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent nuclear fuel until a second repository is in operation [Section 114(d)]. However, Chapter 8 of this EIS analyzes the cumulative impacts from the disposal of all projected spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed Yucca Mountain Repository.

2.3.2 REPOSITORY DESIGN ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The preliminary design concept for the proposed Yucca Mountain Repository analyzed in this EIS is the result of a design process that began with early site characterization activities. The design process identified design alternatives (options) that DOE considered. Some of the design options were eliminated from further detailed study during the design evolution. Examples include placement of the emplacement drifts in the saturated zone (rather than the unsaturated zone); vertical shafts (rather than the gently sloping North and South Ramps); use of drilling and blasting methods for emplacement drift construction (rather than mechanical excavation methods such as tunnel-boring machines); and use of diesel-powered vehicles for waste package emplacement (rather than electrically powered, rail-based vehicles).

DOE recently undertook a comprehensive review and examination of possible design options to provide information for use in support of the suitability recommendation and License Application. Appendix E discusses the design options that DOE considered in this review, and Section 2.1.1 discusses their consideration in this EIS.

2.3.3 NEVADA TRANSPORTATION ALTERNATIVES ELIMINATED FROM DETAILED STUDY

Because rail access is not currently available to the Yucca Mountain site, DOE would have to build a branch rail line from an existing mainline railroad to the repository or transfer rail shipping casks to heavy-haul trucks at an intermodal transfer station to make effective use of rail transportation for shipping spent nuclear fuel and high-level radioactive waste to the repository. Section 2.1.3 describes the 10 implementing rail and intermodal alternatives for Nevada transportation that this EIS evaluates. DOE selected these implementing alternatives based on transportation studies that identified, evaluated, and eliminated other potential Nevada transportation rail and intermodal alternatives (Tappen and Andrews 1990, all; TRW 1995a, all; TRW 1996, all). This section identifies the potential rail and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study.

2.3.3.1 Potential Rail Routes Considered but Eliminated from Further Detailed Study

In the *Preliminary Rail Access Study* (Tappen and Andrews 1990, all), DOE identified 10 potential branch rail line routes to the Yucca Mountain site (Valley, Arden, Jean, Crucero, Ludlow, Mina, Caliente, Carlin, Cherry Creek, and Dike). Figure 2-41 shows these potential rail routes, each named for the area where it would connect to the mainline railroad. Alternatives within each route were developed wherever possible. The routes were chosen to maximize the use of Federal lands, provide access to regional rail carriers, avoid obvious land-use conflicts, and meet current railroad engineering practices. After the development of these rail routes, Lincoln County and the City of Caliente identified three additional routes (identified as Lincoln County Routes A, B, and C).

DOE evaluated these 13 potential rail routes in Tappen and Andrews (1990, all) and reevaluated them in the *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (TRW 1995a, all). One new route, Valley Modified, was added in the 1995 study based on updated information from the Bureau of Land Management on the status of two Wilderness Study Areas that represent possible land-use conflicts for the Valley route in the original evaluation. Three additional alignments—Caliente-Chalk Mountain, Elgin/Rox, and Hancock Summit—were evaluated in the Nevada Potential Repository Preliminary Assessment of the Caliente-Chalk Mountain Rail Corridor. The evaluations reviewed each potential rail corridor to identify land-use compatibility issues (the presence or absence of land-use conflicts, and the potential for mitigation of a conflict if one exists) and for access to regional rail carriers. The evaluations also compared other factors of the routes, including favorable topography (gently sloping rather than rugged terrain) and avoidance of lands withdrawn from public use by Federal action. Based

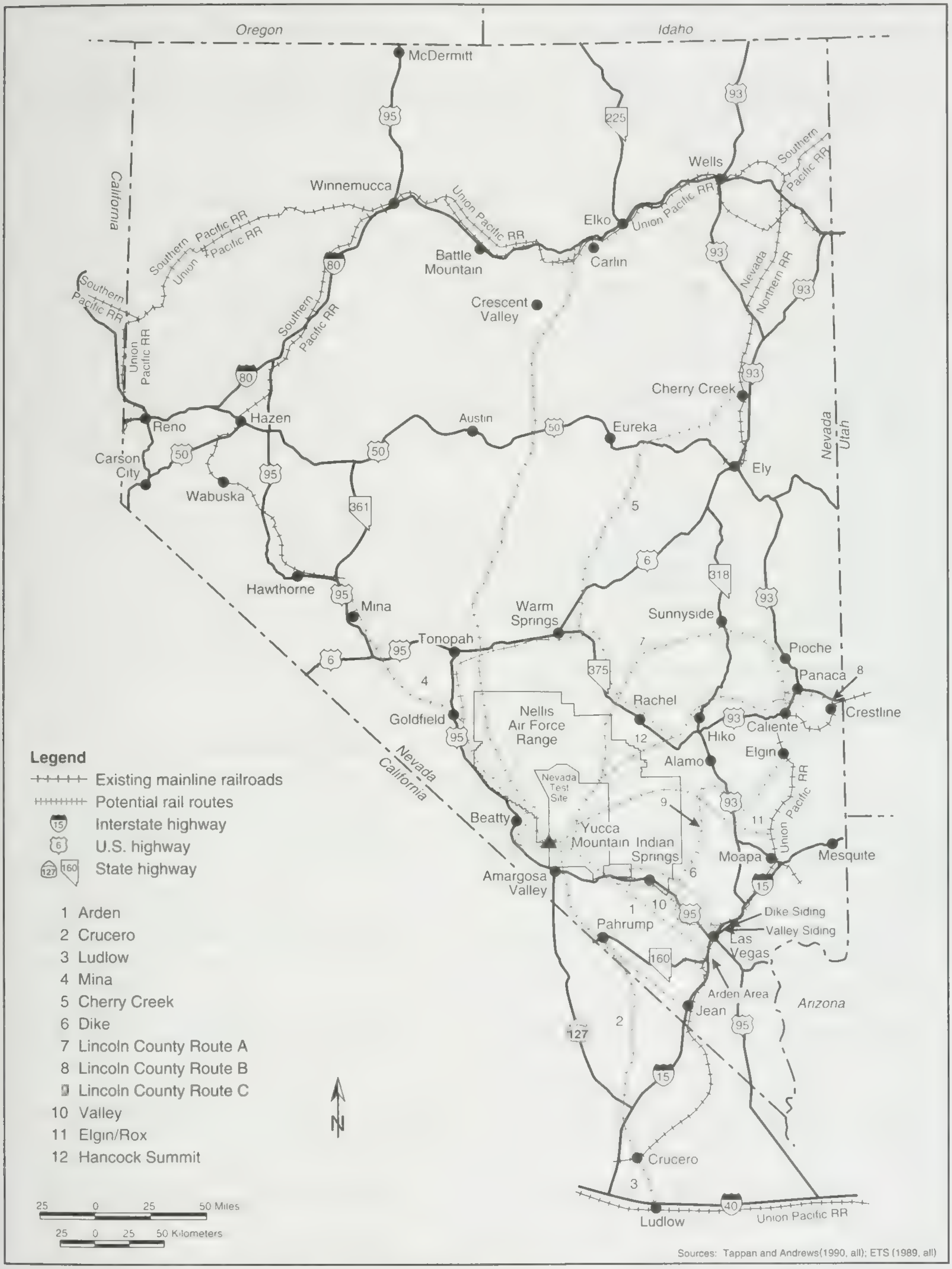


Figure 2-41. Potential rail routes to Yucca Mountain, Nevada, considered but eliminated from detailed study.

on these evaluations, DOE eliminated the Valley, Arden, Crucero, Ludlow, Mina, Cherry Creek, Dike, Elgin/Rox, Hancock Summit, and Lincoln County A, B, and C rail routes from further study.

2.3.3.2 Potential Highway Routes for Heavy-Haul Trucks and Associated Intermodal Transfer Station Locations Considered but Eliminated from Further Detailed Study

DOE identified and evaluated potential highway routes for heavy-haul trucks from existing mainline railroads to the Yucca Mountain site (TRW 1995a, all; TRW 1996, all; TRW 1999d, all). The Department identified highway routes for heavy-haul trucks and associated intermodal transfer station locations to provide reasonable access to existing mainline railroads, to minimize transport length from an existing mainline rail interchange point, and to maximize the use of roads identified by the Nevada Department of Transportation for the highest allowable axle load limits. In addition to the five implementing intermodal alternatives selected for analysis in this EIS (see Section 2.1.3), Figure 2-42 shows highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study. The eliminated alternatives include four routes named for the location of the intermodal transfer station—Apex, Arden, Baker, and Apex/Dry Lake (Las Vegas Bypass)—and three that are representative of routes from the northern Union Pacific mainline railroad (Northern Routes 1, 2, and 3).

DOE considered the development of new roads for dedicated heavy-haul truck shipments. The analysis assumed those routes would be within the corridors identified for potential rail routes, because the selection criteria for heavy-haul routes and rail routes (land-use compatibility issues, access to regional rail carriers, etc.) would be similar (TRW 1996, page 6-3). DOE also considered routes for heavy-haul trucks in the potential rail corridors that could use portions of the existing road system for part of the route length. DOE eliminated the development of a new road for heavy-haul trucks from further detailed evaluation, because the construction of a new branch rail line would be only slightly more expensive and transportation by rail would be safer (no intermodal transfers) and more efficient (TRW 1996, page 6-7).

2.4 Summary of Findings and Comparison of the Proposed Action and the No-Action Alternative

This section summarizes and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative (Section 2.2). Detailed descriptions of the impact analyses are contained in the following chapters:

- Chapter 4 describes the short-term environmental impacts associated with construction, operation and monitoring, and closure of the repository and includes the manufacture of waste disposal containers and shipping casks.
- Chapter 5 describes long-term (postclosure) environmental impacts from the disposal of spent nuclear fuel and high-level radioactive waste in the repository.
- Chapter 6 describes the impacts associated with the transportation of spent nuclear fuel, high-level radioactive waste, other materials, and personnel to and from the repository.
- Chapter 7 describes the short-term and long-term impacts associated with the No-Action Alternative.

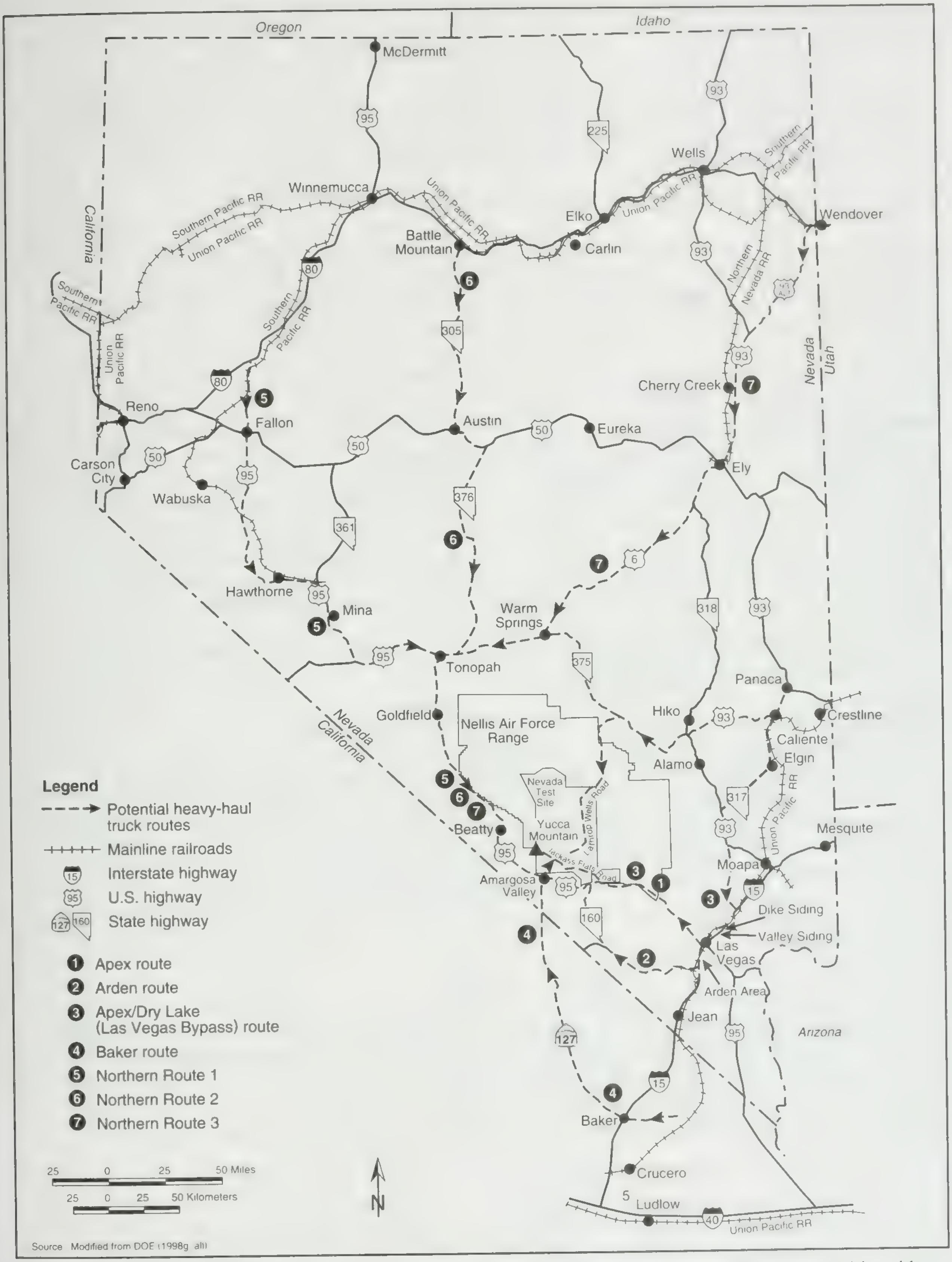


Figure 2-42. Potential highway routes for heavy-haul trucks to Yucca Mountain, Nevada, considered but eliminated from detailed study.

This EIS defines *short-term impacts* as those that would occur until and during the closure of the repository (approximately 100 years following the start of emplacement) and *long-term impacts* as those that would occur after repository closure (after 100 years) and for as long as 10,000 years.

This section summarizes the findings of the EIS analyses and contains a general comparison of the Proposed Action and No-Action Alternative (Section 2.4.1), potential short-term impacts (Section 2.4.2), long-term impacts (Section 2.4.3), and transportation impacts (Section 2.4.4).

2.4.1 PROPOSED ACTION AND NO-ACTION ALTERNATIVE

In general, the EIS analyses showed that the environmental impacts associated with the Proposed Action would be small, as described in Chapters 4, 5, 6, and 8. For some of the resource areas specifically analyzed in this study, there would be no impacts. Table 2-7 provides an overview approach to comparing the Proposed Action and the No-Action Alternative.

Although generally small, environmental impacts would occur under the Proposed Action. DOE would reduce or eliminate many such impacts with mitigation measures or implementation of standard Best Management Practices. Under the No-Action Alternative, the short-term impacts would be the same under Scenarios 1 or 2. Under Scenario 1, DOE would continue to manage spent nuclear fuel and high-level radioactive waste facilities at 5 DOE sites, and commercial utilities would continue to manage their spent nuclear fuel at 72 sites on a long-term basis and to isolate the material from human access with institutional control. Under Scenario 2, with the assumption of no effective institutional control after 100 years, the spent nuclear fuel and high-level radioactive waste storage facilities would begin to deteriorate and radioactive materials could escape to the environment, contaminating the local atmosphere, soils, surface water, and groundwater, thereby representing a considerable human health risk.

2.4.2 SHORT-TERM IMPACTS OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

DOE analyzed short-term impacts (about 100 years) for the Proposed Action and No-Action Alternative in various resource areas. The information presented in Table 2-7 shows that the short-term environmental impacts for the Proposed Action and the No-Action Alternative would generally be small and do not differentiate dramatically between the two alternatives. The analyses also included cost estimates for the two alternatives. Estimated short-term (to 100 years) costs for the Proposed Action would be about $29 billion, and those for the No-Action Alternative would be as much as $57 billion for the same period.

2.4.3 LONG-TERM IMPACTS OF THE PROPOSED ACTION AND THE NO-ACTION ALTERNATIVE

In addition to the short-term impacts described above, DOE assessed the impacts from radiological and nonradiological hazardous materials released over a much longer period (100 years to as long as 10,000 years) after the closure of the repository. Because these projections are based essentially on best available scientific techniques, DOE focused the assessment of long-term impacts on human health, biological resources, surface-water and groundwater resources, and other resource areas for which the analysis determined the information was particularly important and could establish estimates of impacts.

The EIS also examined possible biological impacts from the long-term production of heat by the radioactive materials disposed of in Yucca Mountain. Because there would be no repository activity after approximately 100 years, there would be no changes in land use, employment of workers, and use of water or utilities. The analysis determined that there would be no impacts to land use, noise, socioeconomic resources, cultural resources, surface-water resources, aesthetics, utilities, or site services

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 1 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long term (after closure, about 100 to 10,000 years)	Short term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Land use and ownership	Withdraw about 600 km^2[a] of land now under Federal control; active use of about 3.5 km^2	0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified conflicts for some routes; Valley Modified rail corridor would pass near the Las Vegas Paiute Indian Reservation; some rail corridors could overlap with potential Las Vegas growth; heavy-haul trucks could slow traffic flow; some heavy-haul routes would pass near or through the Moapa and Las Vegas Paiute Indian Reservations	Potential for limited access into the area; the only surface features remaining would be markers	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites
Air quality	Releases and exposures well below regulatory limits (less than 5 percent of limits)	Releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic	No air releases	Releases and exposures well below regulatory limits	Releases and exposures well below regulatory limits	Increases in airborne radiological releases and exposures (potentially exceeding current regulatory limits)
Hydrology (groundwater and surface water)	Water demand well below Nevada State Engineer's ruling on perennial yield (250 to 480 acre-feet[b] per year)	Withdrawal of up to 710 acre-feet[b] from multiple wells and hydrographic areas over 2.5 years	Low-level contamination of groundwater in Amargosa Valley after a few thousand years (estimated concentration would be below drinking water standards)	Small; usage would be small in comparison to other site use	Small; usage would be small in comparison to other site use	Potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites
	Small, minor changes to runoff and infiltration rates, floodplain assessment concluded impacts would be small	Small, minor changes to runoff and infiltration rates, additional floodplain assessments would be performed in the future as necessary	Small, minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Small, minor changes to runoff and infiltration rates	Potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits)

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 2 of 4).

Resource area	Proposed Action: Short-term (through closure, about 100 years) – Repository	Proposed Action: Short-term (through closure, about 100 years) – Transportation	Proposed Action: Long-term (after closure, about 100 to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 2
Biological resources and soils	Loss of about 3.5 km^2 of desert soil, habitat, and vegetation, adverse impacts to threatened desert tortoise (individuals, not the species as a whole), reasonable and prudent measures to minimize impacts, impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small	Loss of 0 to about 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors, adverse impacts to threatened desert tortoise (individuals, not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary	Slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2)	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2
Cultural resources	Repository development would disturb about 3.5 km^2; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Loss of 0 to about 20 km^2 of land disturbed for new transportation routes; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Potential for limited access into the area, opposing Native American viewpoint	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; storage would continue at existing sites; limited potential of disturbing sites	No construction or operation activities; no impacts
Socioeconomics	Estimated peak employment of 1,800 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment; therefore, impacts would be low	Employment increases would range from less than 1 percent to 5.7 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county; therefore, impacts would be low	No workers, no impacts	Small; population and employment changes would be small compared to totals in the regions	Small; population and employment changes would be small compared to totals in the regions	No workers; no impacts
Occupational and public health and safety						
Public						
Radiological (LCFs)						
MEI[c]	1.9×10^{5} to 5.1×10^{5}	1.6×10^{4} to 1.2×10^{3}	1.9×10^{8} to 4.4×10^{5}	4.3×10^{6}	1.3×10^{6}	(d)
Population	0.14 to 0.41	3 to 18	5.5×10^{5} to 5.3×10^{4}	0.41	3	3,300[e]
Nonradiological	Exposures well below regulatory limits	Exposures below regulatory limits; pollutants from vehicle traffic and trains	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 3 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation			Scenario 1	Scenario 2
Occupational and public health and safety (continued)						
Workers (involved and noninvolved)						
Radiological (LCFs)	3 to 4	3 to 11	No workers, no impacts	16	12	No workers, no impacts
Nonradiological fatalities (includes commuting traffic fatalities)	1 to 2	11 to 16[f]	No workers, no impacts	9	1,080	No workers, no impacts
Accidents						
Probability (frequency per year)	8.6×10^{7} to 1.1×10^{2}	1.4×10^{7} to 1.9×10^{-7}	No credible accidents	3.2×10^{6}	3.2×10^{6}	3.2×10^{6}
Public						
Radiological (LCFs)						
MEI	2.9×10^{13} to 2.1×10^{-6}	0.002 to 0.013	Not applicable	No impacts	No impacts	Not applicable
Population	1.0×10^{11} to 7.8×10^{-5}	0.02 to 0.07	Not applicable	No impacts	No impacts	3 to 13
Workers	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts
Noise	Impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels – controls and protection used as necessary	Transient and not excessive, less than 90 dBA[g]	No activities, therefore, no noise	Transient and not excessive, less than 90 dBA	Transient and not excessive, less than 90 dBA	No activities, therefore, no noise
Aesthetics	Low adverse impacts to aesthetic or visual resources in the region	Low, temporary, and transient; possible conflict with visual resource management goals for Jean rail corridor	Small; only surface features remaining would be markers	Small; storage would continue at existing sites; expansion as needed	Small; storage would continue at existing sites; expansion as needed	Small; aesthetic value decreases as facilities degrade
Utilities, energy, materials, and site services	Use of materials would be very small in comparison to amounts used in the region electric power delivery system to the Yucca Mountain site would have to be enhanced.	Use of materials and energy would be small in comparison to amounts used nationally	No use of materials or energy	Small; materials and energy use would be small compared to total site use	Small; materials and energy use would be small compared to total site use	No use of materials or energy

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 4 of 4).

Resource area	Proposed Action: Short-term (through closure, about 100 years) Repository	Proposed Action: Short-term (through closure, about 100 years) Transportation	Proposed Action: Long term (after closure, about 100 to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years) Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years) Scenario 2
Management of site-generated waste and hazardous materials	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity, other wastes would be managed offsite and some waste potentially at an onsite landfill	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity, other wastes would be managed offsite and some waste potentially at an onsite landfill	No waste generated or hazardous materials used	Small, waste generated and materials used would be small compared to total site generation and use	Small; waste generated and materials used would be small compared to total site generation and use	No waste generated or hazardous materials used
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations	No disproportionately high and adverse impacts to minority or low-income populations	Potential for disproportionately high and adverse impacts to minority or low-income populations

a. km^2 = square kilometers; to covert to acres, multiply by 247.1.
b. To convert acre-feet to cubic meters, multiply by 1233.49.
c. LCF = latent cancer fatality; MEI = maximally exposed individual.
d. The maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.
e. Downstream exposed population of approximately 3.9 billion over 10,000 years.
f. As many as 8 of these fatalities could be members of the public; fatalities include commuting traffic fatalities.
g. dBA = A-weighted decibels, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

from the Proposed Action and limited impacts from the No-Action Alternative, depending on the scenario. The analysis led to the following conclusions:

- From 0.04 to 0.4 square kilometer (10 to 100 acres) of land could be contaminated to the extent it would not be usable for long periods near each of the 77 sites for No-Action Scenario 2. There could be accompanying impacts on biological resources, socioeconomic conditions, cultural resources, and aesthetic resources for long periods. Such impacts for the Proposed Action and No-Action Scenario 1 would be very small.

- For No-Action Scenario 2, there could be low levels of contamination in the surface watershed and high concentrations of contaminants in the groundwater downstream of the 77 sites for long periods. There would be no such impacts for No-Action Scenario 1. For the Proposed Action, there could be low levels of contamination in the groundwater in the Amargosa Desert for a long period.

- Projected radiological impacts to the public for the first 10,000 years for the Proposed Action would be low (0.000055 to 0.00053 latent cancer fatality per year) compared to No-Action Scenario 2 (3,300 latent cancer fatalities).

- Radionuclides would be released for a long period of time under the Proposed Action and peak doses would occur hundreds of thousand years after closure of the repository.

- Projected long-term fatalities associated with No-Action Scenario 1 would be about 1,000, primarily to the workforce at the storage sites.

- Risks associated with sabotage and materials diversion in relation to the fissionable material stored at the 77 sites would be much greater than they would be if the fissionable material were in a monitored deep geologic repository.

The projected cost associated with No-Action Scenario 1 would be approximately $600 million a year (1998 dollars) for 9,900 years. Projected long-term costs for the Proposed Action would be very low while there would be none for No-Action Scenario 2 due to the lack of institutional control.

2.4.4 IMPACTS OF TRANSPORTATION SCENARIOS

2.4.4.1 National Transportation

This section summarizes and compares transportation-related environmental impacts for the movement of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site. Table 2-8 compares the environmental impacts for the two national transportation scenarios analyzed, mostly rail and mostly legal-weight truck (see Section 2.1.3.2). Because DOE does not know the actual mix for these potential national transportation modes, the analyses used these two scenarios to bound the impacts from transportation activities that would move spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. In addition, Table 2-8 lists estimates of the environmental impacts associated with transportation activities in Nevada.

The values listed in Table 2-8 are limited to radiological impacts. As discussed in more detail in Chapter 6, shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be a small fraction of the overall railroad and highway shipping activity in the United States. Thus, the incremental impacts from shipments to Yucca Mountain for the resource areas would be small in comparison to background impacts from all shipping activities, with the exception of potential radiological impacts.

Table 2-8. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48	48
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	11,000	1,900 - 2,300[a]
	Latent cancer fatality incidence	4.5	0.8 - 0.9[a]
Public	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	2.4	0.31
	Individual latent cancer fatality probability	0.001	0.00016
	Collective dose (person-rem)	35,000	3,300 - 5,000[a]
	Latent cancer fatality incidence	18	1.6 - 2.5[a]
	Incident-free vehicle emissions impacts		
	Fatalities	0.6	0.3
Public	*Radiological impacts from maximum reasonably foreseeable accident scenario*		
	Probability (per year)	1.9 in 10,000,000	1.4 in 10,000,000
	Maximally exposed individual (rem)	3.9	26
	Individual latent cancer fatality probability	0.002	0.013
	Collective dose (person-rem)	9,400	61,000
	Latent cancer fatality incidence	4.7	31
Public and transportation workers	*Fatalities from vehicular accidents*	3.9	3.6

a. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.

The following conclusions can be drawn from the analysis results summarized in Table 2-8:

- Radiological impacts from maximum foreseeable accident scenarios during the transportation of spent nuclear fuel and high-level radioactive waste would be lower for the mostly legal-weight truck case.
- Impacts from the transportation of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site would be low for either national shipping mode.
- Radiological impacts to the public and to workers for normal transportation activities would be lower for the mostly rail scenario.

Most of the occupational and public health and safety impacts to the public and to workers would occur during the repository operating and monitoring phase.

Incremental differences in short-term impacts for the thermal load scenarios would be small, generally by less than a factor of about 2. Short-term impacts would generally be largest for the low thermal load and lowest for the high thermal load.

2.4.4.2 Nevada Transportation

For shipments coming into the State of Nevada by rail, there is no rail line to connect the national rail routes with the Yucca Mountain site (see Section 2.1.3.3). As a consequence, DOE evaluated the impacts in Nevada of moving spent nuclear fuel and high-level radioactive waste to the site using 10 implementing alternatives. These included five potential corridors for a new branch rail line (see Section 2.1.3.3.2) and five potential combinations of intermodal transfer stations and highway routes for heavy-haul trucks (see Section 2.1.3.3.3).

Tables 2-9 and 2-10 compare the impacts from transportation activities in potential Nevada rail corridors and heavy-haul truck corridors, respectively. In addition, they list impacts associated with engineering attributes for each implementing alternative. These engineering factors include cost, institutional acceptability of the route, construction and schedule risk, and operational compatibility. Additional attributes could affect a decision on the choice of a transportation mode or route in Nevada.

The following conclusions can be drawn from the information in Tables 2-9 and 2-10:

- Environmental impacts for each of the 10 implementing alternatives would be small.
- With the exception of collective dose, the environmental impacts for shipment by legal-weight truck in Nevada would be smaller than those from the 10 implementing alternatives associated with incoming shipments by rail. However, even for shipment by rail or heavy-haul truck in Nevada, the projected collective dose impacts would be small (approximately 2 latent cancer fatalities to both the public and transportation workers).
- With the exception of land use, differences in environmental impacts for the 10 implementing alternatives related to incoming shipments by rail would be small, so environmental impacts do not appear to be a major factor in the selection of transportation mode, route, or corridor in Nevada for incoming rail shipments.
- For land use, the Caliente-Chalk Mountain routes for a rail corridor and for a highway route for heavy-haul trucks would have conflicts with ongoing national defense activities at the Nellis Air Force Range.
- Impacts to cultural resources for any of the potential implementing alternative routes or corridors cannot be fully assessed until more detailed archaeological and ethnographic studies are conducted, but they are likely to be similar to one another. Impacts to Native American values could occur from the use of any of the routes including the use of highways in Nevada by legal-weight trucks that would pass through the Moapa and Las Vegas Paiute Indian reservations.

2.5 Collection of Information and Analyses

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a monitored geologic repository for spent nuclear fuel and high-level radioactive waste. The Department used the information from these studies in the analyses described in this EIS. Because some of these studies are ongoing, some of the information is incomplete.

The complexity and variability of the natural system at Yucca Mountain, the long periods evaluated, and factors such as the use of incomplete information or the unavailability of information have resulted in a certain degree of uncertainty associated with the analyses and findings in this EIS. DOE believes that it is important that the EIS identify the use of incomplete and unavailable information and uncertainty to enable an understanding of its findings. It is also important to understand that research can produce results or conclusions that might disagree with other research. The interpretation of results and conclusions has resulted in the development of views that differ from those that DOE presents in this EIS. DOE has received input from a number of organizations interested in the Proposed Action or No-Action Alternative or from potential recipients of impacts from those actions. These organizations include among others the State of Nevada, local governments, and Native American groups. Their input includes documents that present research or information that in some cases disagrees with the views that DOE presents in this EIS. The Department reviewed these documents and evaluated their findings for inclusion as part of the EIS analyses. If the information represents a substantive view, DOE has made every effort to incorporate that view in the EIS and to identify its source.

Table 2-9. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Land use and ownership						
Disturbed land (square kilometers)[a]	18	19	12	9	5	None
Private land (square kilometers)	0.9	7	0.8	3.6	0	None
Nellis Air Force Base land (square kilometers)	20	19	22	0	10	None
Air quality						
PM_{10} (construction)	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line construction would not be a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction would not be a significant source of pollution	No construction
CO (operations)	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[b]	710	660	480	410	320	None
Water use (number of wells)	64	67	43	23	20	None
Biological resources and soils	Low	Low	Low	Low	Low	None
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[c]	42	39	33	26	13	Low
Steel (thousand metric tons)[d]	71	72	48	26	22	None

Table 2-9. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Concrete (thousand metric tons)[e]	420	400	280	150	130	None
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	1,200 (< 1% to 4%)	1,100 (< 1%)	910 (< 1% to 5.7%)	720 (< 1%)	350 (< 1%)	Low
Peak real disposable income (million dollars)	27	25	19	16	7	Low
Peak incremental Gross Regional Product (million dollars)	49	44	35	29	14	NA[f]
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	None
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	250	240	220	170	130	NA
Lost workday cases	130	120	110	90	70	NA
Fatalities	1.3	1.2	1	0.9	0.5	NA
Collective dose (person-rem [LCFs])						
Workers	430 [0.17]	470 [0.19]	390 [0.16]	400 [0.16]	380 [0.15]	1,600 [0.63]
Public	390 [0.20]	420 [0.21]	380 [0.19]	430 [0.21]	380 [0.19]	2,800 [1.4]
Fatalities from vehicle emissions	0.0019	0.0025	0.0017	0.014	0.0018	0.005
Traffic accident fatalities						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA[f]
SNF[g] and HLW[h] shipping	0.13	0.15	0.11	0.11	0.1	0.5
Radiological impacts, accident scenarios						
Maximum exposed individual (rem)	26	26	26	26	26	3.9
Individual latent cancer fatality probability	0.02	0.02	0.02	0.02	0.02	0.002
Collective dose	0.09	0.1	0.09	0.15	0.09	0.5
Latent cancer fatalities	0.00005	0.00005	0.00004	0.00008	0.00004	0.0002

a. To convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. To convert liters to gallons, multiply by 0.26418.
d. To convert metric tons to tons, multiply by 1.1023.
e. To convert cubic feet to cubic meters, multiply by 0.028317.
f. NA = not applicable.
g. SNF = spent nuclear fuel.
h. HLW = high-level radioactive waste.

Table 2-10. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Land use and ownership						
Disturbed land (square kilometers)[a]	0.28	0.24	0.24	0.2	0.2	None
Private land (square kilometers)	0	0	0	0	0	None
Nellis Air Force Base land (square kilometers)	0	0	0	0	0	None
Air quality						
PM_{10} (construction)	Areas in attainment of air quality standards - highway upgrades not a significant source of pollution	Areas in attainment of air quality standards highway upgrades not a significant source of pollution	Except Clark County, areas in attainment of air quality standards - highway upgrades not a significant source of pollution	48% of GCR Threshold for IMT construction	48% of GCR Threshold for IMT construction	No construction
CO (operations)	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[b]	100	60	44	8	8	None
Water use (number of wells)	16	5	7	Truck water	Truck water	None
Biological resources and soils	Low	Low	Low	Low	Low	None
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[c] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[d]	13	4.7	5.5	1.7	1.6	Low
Steel (metric tons)[e]	49	14	21	2.3	2.3	None
Concrete (thousand metric tons)[f]	1.8	0.5	0.8	0.1	0.1	None
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 2-10. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Socioeconomics						
New jobs (percent of workforce in affected counties)	1,000 (< 1% to 2.3%)	830 (< 1% to 2.6%)	810 (< 1% to 2%)	720 (< 1%)	540 (< 1%)	Low
Peak real disposable personal income (million dollars)	25	20	20	20	15	Low
Peak incremental Gross Regional Product (million dollars)	42	35	35	34	26	Low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	None
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	340	330	300	180	180	NA[g]
Lost workday cases	190	180	160	100	100	NA
Fatalities	0.7	0.6	0.6	0.4	0.4	NA
Incident-free health and safety (continued)						
Collective dose (person-rem [LCFs])						
Workers	780 [0.31]	710 [0.29]	740 [0.30]	710 [0.29]	690 [0.28]	1,600 [0.63]
Public	2,100 [1.0]	1,200 [0.62]	1,600 [0.77]	1,000 [0.51]	940 [0.47]	2,800 [1.4]
Fatalities from vehicle emissions	0.0016	0.0012	0.0013	0.012	0.0012	0.005
Traffic accident fatalities						
Construction and operations workforce	5.6	2.9	3.4	2.0	2.0	NA[g]
SNF[h] and HLW[i] shipping	0.73	0.42	0.54	0.33	0.31	0.5
Radiological impacts, accident scenarios						
Maximum exposed individual (rem)	26	26	26	26	26	3.9
Individual latent cancer fatality probability	0.02	0.02	0.02	0.02	0.02	0.002
Collective dose	0.29	0.26	0.72	4.1	0.67	0.5
Latent cancer fatalities	0.0001	0.0001	0.0004	0.002	0.0003	0.0002

a. To convert square kilometers to acres, multiply by 247.1
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. IMT = intermodal transfer.
d. To convert liters to gallons, multiply by 0.26418.
e. To convert metric tons to tons, multiply by 1.1023.
f. To convert cubic feet to cubic meters, multiply by 0.028317.
g. NA = not applicable.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.

2.5.1 INCOMPLETE OR UNAVAILABLE INFORMATION

Some of the analyses in this EIS had to use incomplete information. To ensure an understanding of the status of its information, DOE has identified the use of incomplete information or the unavailability of information in the EIS in accordance with the Council on Environmental Quality regulations pertaining to incomplete and unavailable information (40 CFR 1502.22). Such cases describe the basis for the analyses, including assumptions, the use of preliminary information, or conclusions from draft or incomplete studies. DOE continues to study issues relevant to understanding what could happen in the future at Yucca Mountain and the potential impacts associated with its use as a repository. As a result, the Final EIS will include information that was not available for the Draft EIS. In addition, DOE might not complete some of the studies and design development for the repository until after it has issued the Final EIS. DOE believes, however, that sufficient information is currently available to assess the range of impacts that could result from either the Proposed Action or the No-Action Alternative.

2.5.2 UNCERTAINTY

The results and conclusions of analyses often have some associated uncertainty. The uncertainty could be the result of the assumptions used, the complexity and variability of the process being analyzed, the use of incomplete information, or the unavailability of information. To enable an understanding of the status of its findings, this EIS contains descriptions of the uncertainties, if any, associated with the results and conclusions presented.

2.5.3 OPPOSING VIEWS

In this EIS, opposing views are defined as differing views or opinions currently held by organizations or individuals outside DOE. These views are considered to be opposing if they include or rely on data or methods that DOE is not currently using in its own impact analysis. In addition, these views are reasonably based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS.

DOE has attempted to identify and address the range of opposing views in this EIS. The Department identified potential opposing views by reviewing published or other information in the public domain. Sources of information included reports from universities, other Federal agencies, the State of Nevada, counties, municipalities, other local governments, and Native American groups. DOE reviewed the potential opposing views to determine if they:

- Address issues analyzed in the EIS
- Differ from the DOE position
- Are based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS
- Have significant basic differences in the data or methods used in the analysis or to the impacts described in the EIS

DOE has included potential opposing views that met the above criteria in the EIS where it discusses the particular subject. For example, opposing views on the groundwater system are discussed in the sections on groundwater.

2.6 Preferred Alternative

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The analyses in this EIS did not identify any potential environmental impacts that would be a basis for not proceeding with the Proposed Action. DOE has not chosen any transportation mode, corridor, or route as preferred at this time.

DOE recognizes that implementation of the preferred alternative would require the completion of a number of actions. As part of this process, the Secretary of Energy is to:

- Undertake (and complete) site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The NWPA also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will notify the Governor and legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

If, after a recommendation by the Secretary, the President considers the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the legislature submits a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

In determining whether to recommend the Yucca Mountain site to the President, DOE would consider not only the potential environmental impacts identified in this EIS, but also other factors. Those factors could include those identified through public input, as well as other available information. Examples of such other possible factors include the following:

- Ability to obtain necessary approvals, license and permits
- Ability to fulfill stakeholder agreements
- Consistency with DOE mission
- Assurance of safety
- Facility construction and operation flexibility

- Cost of implementation
- Ability to mitigate adverse impacts

As part of the Proposed Action, the EIS analyzes the impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. As part of this analysis, the EIS includes information, such as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada, that might not lead to near-term decisions. It is uncertain at this time when DOE would make these transportation-related decisions. If and when it is appropriate to make such decisions, DOE believes that the EIS provides the information necessary to make these decisions. However, measures to implement those decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station, or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

3

Affected Environment

3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the baseline against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. (Affected units of local government include county governments near the potential repository site and along potential transportation routes within Nevada.)

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files,* contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)

- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)

- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)

- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and wetlands, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, community services, and transportation services in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from background radiation; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise:* Noise sources and levels of noise that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of low-income and minority populations in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to the proposed repository. Human health risks from exposure to airborne contaminant emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DOE 1998h, page 1). Yucca Mountain site characterization activities began in 1989 and will continue until 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. By 2001, these activities

Table 3-1. Regions of influence for the proposed Yucca Mountain Repository.

Subject area	Region of influence
Land use and ownership	Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1).
Air and climate	An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2).
Geology	The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3).
Hydrology	*Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants. *Groundwater:* aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5).
Cultural resources	Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6).
Socioeconomic environment	Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8).
Noise	Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9).
Aesthetics	Approximate boundary of analyzed land withdrawal area (Section 3.1.10).
Utilities, energy, and materials	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13).

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

will have disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (TRW 1999a, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists existing facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site.

Table 3-2. Existing facilities, structures, and disturbances at Yucca Mountain.[a]

Yucca Mountain	Area 25 Central Support Site
Exploratory Studies Facility (North Portal pad and supporting structures)	Field Operations Center
Exploratory Studies Facility (South Portal pad)	Hydrologic research facility
Cross drift[b]	Sample management facility and warehouse
Concrete batch plant and precast yard	Radiological studies facility
Fill borrow pits (3) and screening plants	Meteorology/air quality studies facility
Subdock equipment storage facility	Project accumulation area for hazardous waste
Equipment/supplies laydown yard	Gas station
Hydrocarbon management facility	Maintenance facility
Boxcar equipment and supplies yard	U.S. Geological Survey technical warehouse
Water wells J-12 and J-13	Tunnel rescue facility
Excavated rock storage pile	Sewage lagoon operated by the Nevada Test Site
Topsoil storage pile	
Explosives storage magazines (2)	
Water booster pump and distribution system	
Boreholes (about 300)	
Trenches and test pits (about 200)	
Busted Butte geologic test drift	
Fran Ridge heated-block test facility	
Water infiltration test sites	
Meteorological monitoring towers	
Air quality monitoring sites	
Radiological monitoring sites	
Ecological study plots	
Reclamation study plots	
Septic system	
Roads	

a. Source: Modified from DOE (1998i, all).
b. Drift is a mining term for a horizontal tunnel.

3.1.1 LAND USE AND OWNERSHIP

The region of influence for land use and ownership includes the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3

describes the analyzed land withdrawal area for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. TRW (1999f, all) is the basis of the information in this section unless otherwise noted.

3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

Table 3-3. Nevada land areas and controlling authorities (square kilometers).[a,b]

Authority	Area
State, local, county, or private	42,000
Bureau of Land Management	190,000
Department of Defense	13,000
Department of Energy	3,500
Other Federal authorities	31,000
Native American tribes	5,000

a. Source: TRW (1999f, page 1).
b. To convert square kilometers to square miles, multiply by 0.3861.

The Nevada Test Site, which is a DOE facility, covers about 3,500 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all). The U.S. Air Force operates the Nellis Air Force Range, which covers about 13,000 square kilometers (5,000 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (USAF 1999, all).

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Refuge and the Ash Meadows National Wildlife Range, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). These areas provide habitat for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which is in California approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada south of Ash Meadows is also administered by the National Park Service (Figure 3-1).

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near the Towns of Beatty, Amargosa Valley, and Indian Springs in Nevada. There are also larger private tracts in the agricultural areas of the Las Vegas Valley, near Pahrump, and in the Amargosa Desert south of the Town of Amargosa Valley. The closest year-round housing is at Lathrop Wells in the Amargosa Valley, about 22 kilometers (14 miles) south of the site. There is

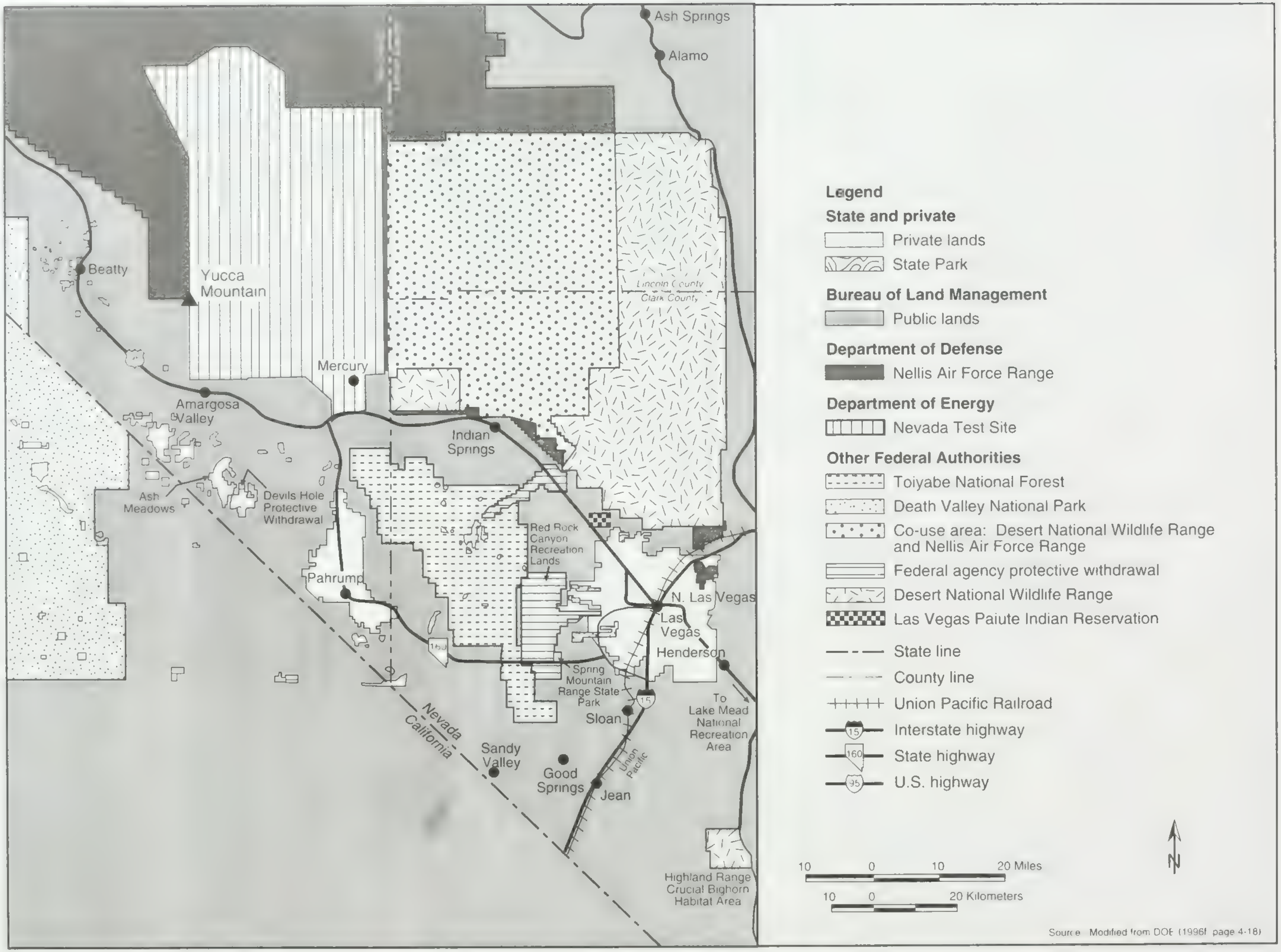


Figure 3-1. Land use and ownership in the Yucca Mountain region.

farming primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository in the Town of Amargosa Valley (Figure 3-1).

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (BLM 1988, all). This reservation comprises 210 square kilometers (81 square miles). The land in this reservation is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository rock (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Repository Rock"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim in the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (29 square miles) of Nellis land for Yucca Mountain site characterization activities (BLM 1994a, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (90 square miles) of Nevada Test Site land for site characterization activities.

3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission licensing conditions for a monitored geologic repository (10 CFR Part 60) include a requirement that DOE have either ownership or permanent control of the lands for which it is seeking a repository license. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to the repository operations areas. As a consequence, DOE used a land withdrawal area as the basis for analysis in this EIS.

Figure 3-2. Land use and ownership in the analyzed land withdrawal area and vicinity.

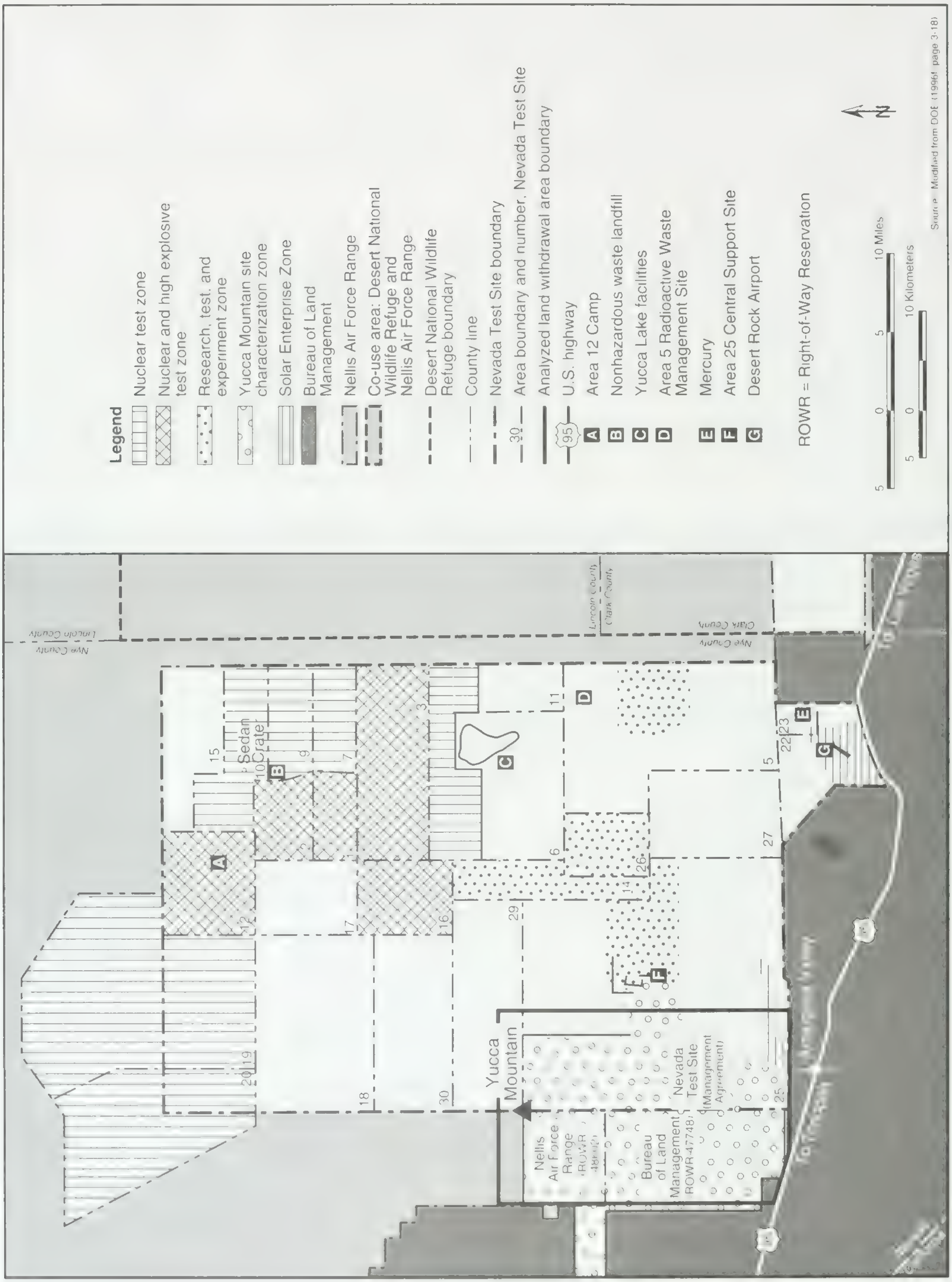


Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4).

Table 3-4. Current land ownership and public accessibility to the analyzed land withdrawal area.[a,b]

Agency	Area (square kilometers)[c]	Current accessibility
DOE (Nevada Test Site)	300	No public access
U.S. Air Force (Nellis Air Force Range)	97	No public access
Bureau of Land Management (public land)	200	Public access
Private land (one patented mining claim)	1	No public access

a. Source: DOE (1998j, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws except for an existing patented mining claim. That claim (No. 27-83-0002) covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders (a raw material used in the manufacture of cinderblocks). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (Western Shoshone v. United States 1997, all). The legal battle over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1977, the Commission granted a final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that no payment has been made (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission's final award and, as a consequence, the aboriginal title of the land had been extinguished.

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Clark and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) and for particulate matter. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (TRW 1999g, all) is the basis for the information provided in this section.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if ambient concentrations of that pollutant are below National Ambient Air Quality Standards (Table 3-5).

Table 3-5. National and Nevada ambient air quality standards.[a]

Pollutant	Primary and Secondary NAAQS,[b] except as noted: Period	Concentration	Highest measured Yucca Mountain concentration[c]	Nevada standards[d]
Sulfur dioxide	Annual[e]	0.03 part per million	0.002	Same
	24-hour[f]	0.14 part per million	0.002	
Sulfur dioxide (secondary)	3-hour[f]	0.5 part per million	0.002	
PM_{10}[g]	Annual[h]	50 micrograms per cubic meter	12	Same
	24-hour[i]	150 micrograms per cubic meter	67	
$PM_{2.5}$[j]	Annual[h]	15 micrograms per cubic meter	N/A[k]	None
	24-hour[l]	65 micrograms per cubic meter	N/A	
Carbon monoxide	8-hour[f]	9 parts per million	0.2	Same[m]
	1-hour[f]	35 parts per million	0.2	Same
Nitrogen dioxide	Annual[e]	0.053 part per million	0.002	Same
Ozone	1-hour[n]	0.12 part per million	0.1	Same
	8-hour[o]	0.08 part per million	N/A	None

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. PM_{10} = particulate matter with a diameter less than 10 micrometers (0.0004 inch). If and until the revised State Implementation Plan is approved 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard implemented in 1998. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

(Ambient air is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national PM_{10} standard, but in nonattainment with the more restrictive California standard (CEPA 1998, pages H6 to H35).

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (EPA 1999a, all; EPA 1999b, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DOE 1996f, page 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (NDCNR 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below

applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

In 1997, the Environmental Protection Agency issued National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than fugitive dust sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas.

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected, although these concentrations were barely detectable (0.081 to 0.096 part per million) and ranged from 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California. In 1998, the Environmental Protection Agency revoked the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replaced it with a new 8-hour ozone standard. Nonattainment areas for the new ozone standard will be designated in 2000.

3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DOE 1998a, Volume 1, page 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (TRW 1997a, pages A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (TRW 1997a, pages 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at

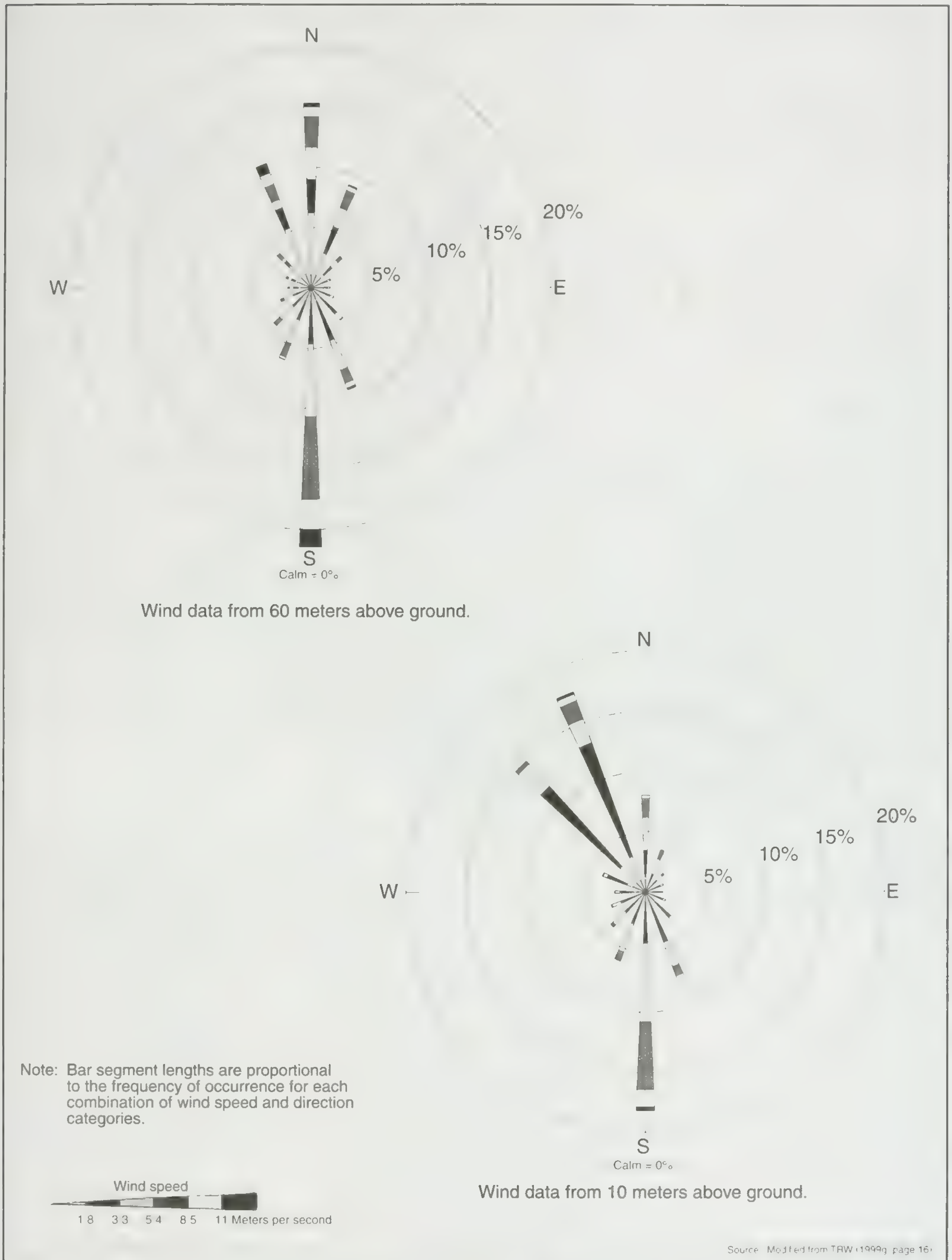


Figure 3-3. Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in Amargosa Valley about 50 kilometers (30 miles) south of the site (TRW 1997a, page 4-26).

3.1.3 GEOLOGY

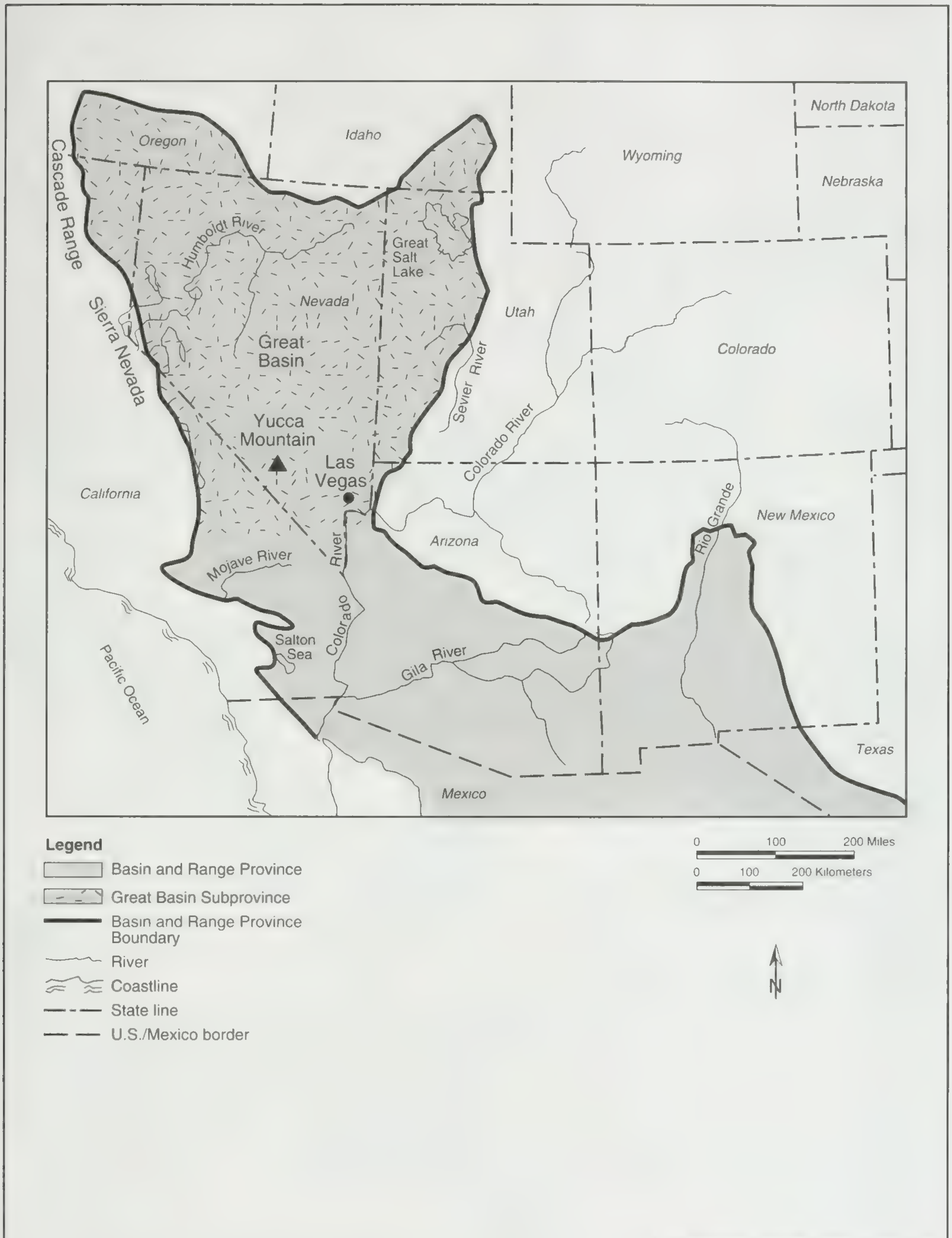
DOE has studied the existing physiographic setting (characteristic landforms), stratigraphy (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the baseline conditions of the region's geology. DOE investigated seismicity (earthquake activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository. Unless otherwise referenced, the information in this section is from the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all), the *Yucca Mountain Site Description* (TRW 1998a, all), or the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a, all).

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the Great Basin subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area.

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Most valleys are called *closed basins* because they lack a drainage outlet. Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic upland, 6 to 10 kilometers (4 to 6 miles) wide and 40 kilometers (25 miles) long. This mountain is part of



Source: Modified from TRW (1998a, Figure 1.1-4, page F1.1-4).

Figure 3-4. Basin and Range Physiographic Province and Great Basin Subprovince.

a volcanic plateau formed between about 14 million and 11.5 million years ago (Sawyer et al. 1994, page 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of deformation associated with past interactions of crustal segments (plates) (TRW 1998a, page 3.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (TRW 1998a, page 3.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

> **CALDERA**
>
> A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain is between 1,400 meters (4,600 feet) and 1,500 meters (4,900 feet) above sea level. The bottoms of the adjacent valleys are approximately 600 meters (2,000 feet) lower.

Yucca Mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Valley, and on the east by the Calico Hills and by Jackass Flats, which contains Fortymile Wash (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River (see Section 3.1.4.1) and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and Bare Mountain. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the Amargosa River. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River.

Site Stratigraphy and Lithology

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies Paleozoic sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits. The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

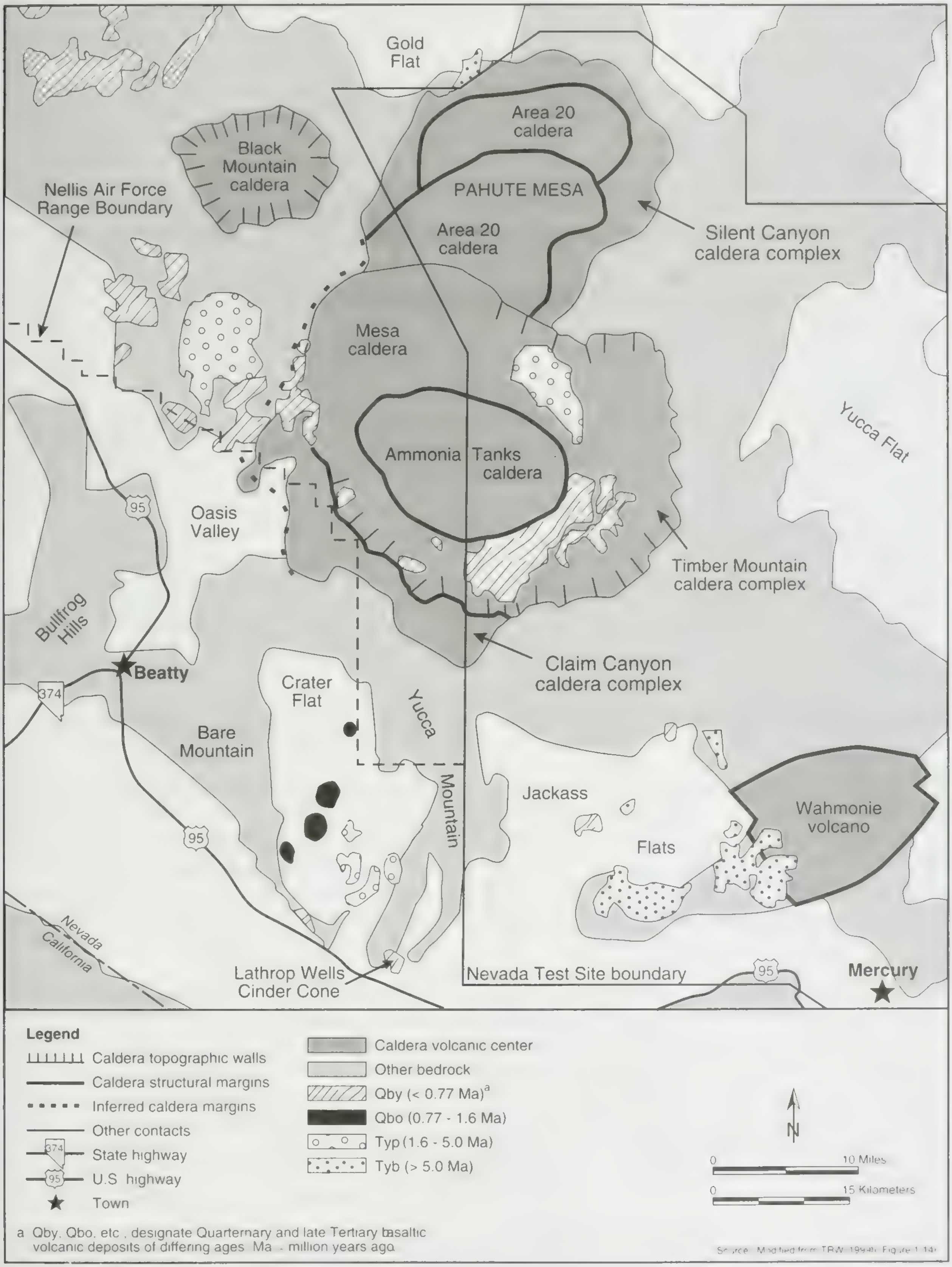


Figure 3-5. Calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

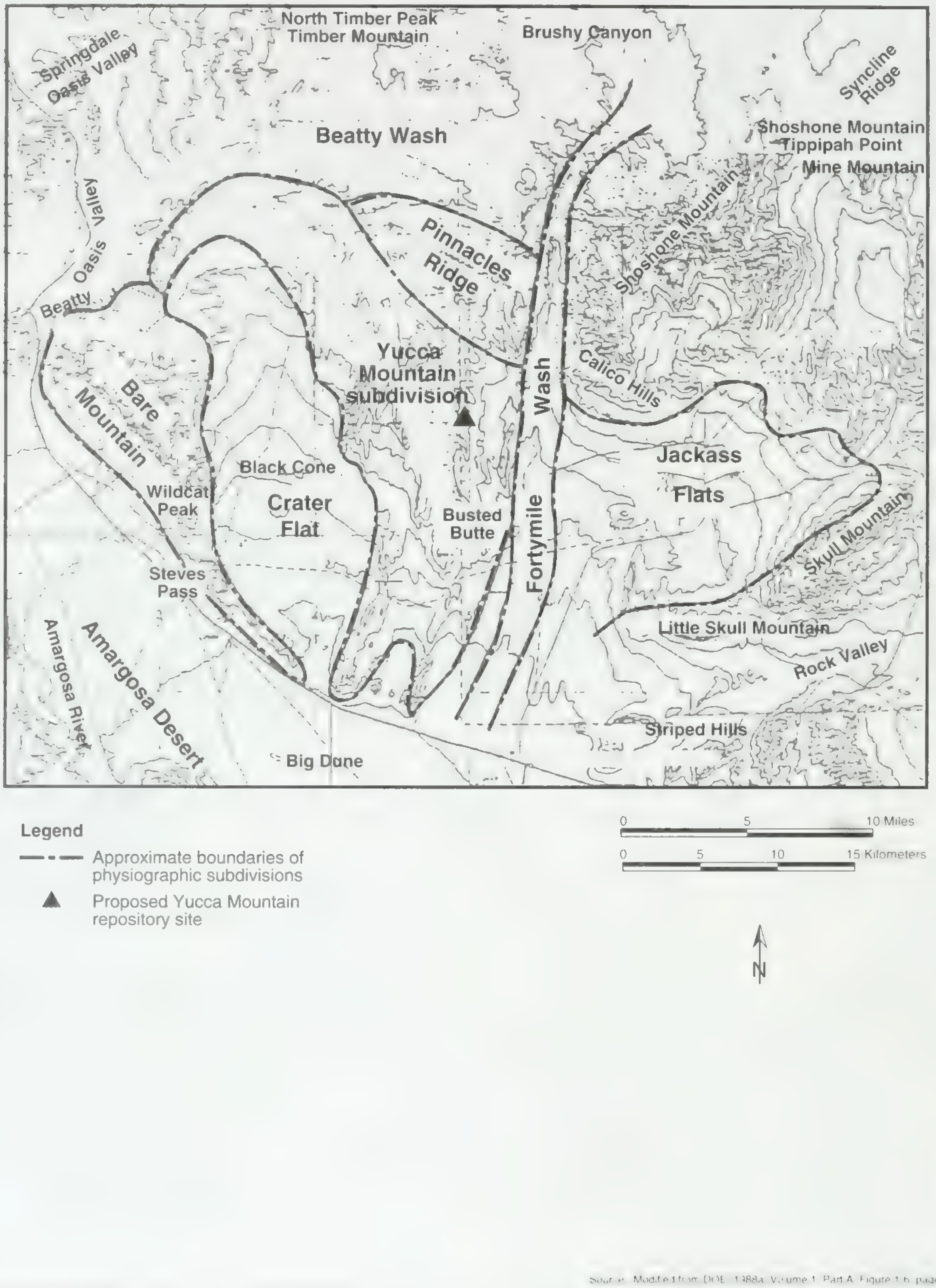


Figure 3-6. Physiographic subdivisions in the Yucca Mountain vicinity.

Table 3-6. Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

Geologic age designation	Major rock types (lithologies)
Cenozoic Era	
Quaternary Period (< 1.6 Ma)[b]	Alluvium; basalt
Tertiary Period (< 65 - 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major volcanic formations at Yucca Mountain.
Mesozoic Era (240 - 65 Ma)	No rocks of this age found in Yucca Mountain region.
Paleozoic Era (570 - 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-15), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods.
Precambrian Era (> 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement."

a. Source: Adapted from TRW (1999h, Section 1.2, pages 1-8 to 1-15).
b. Ma = approximate years ago in millions.

Only Tertiary and younger rocks are exposed at Yucca Mountain. Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain (Figure 3-6) about 15 kilometers (9 miles) west of Yucca Mountain and at other localities scattered around the region. Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one borehole, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (Carr et al. 1986, page 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DOE 1996g, all). The following paragraphs provide a general summary based on the *Yucca Mountain Site Description* (TRW 1998a, pages 3.5-1 to 3.5-28).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuff (or pyroclastic flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows. As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock matrix). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the

Table 3-7. Tertiary volcanic rock sequence at Yucca Mountain.[a]

Name	Age millions of years)	Thickness (meters)[b]	Characteristics
Timber Mountain Group			
• Ammonia Tanks Tuff	11.5	215	Welded to nonweld rhyolite tuff; exposed in southern Crater Flat.
• Rainier Mesa Tuff	11.6	< 30 - 40	Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults.
Post-Tiva Canyon, pre-Rainier Mesa Tuffs	12.5	0 - 61	Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain.
Paintbrush Group			Four formations (below) interlayered locally with lava flows and reworked volcanic deposits.
• Tiva Canyon Tuff	12.7	< 50 - 175	Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain.
• Yucca Mountain Tuff	--[c]	0 - 45	Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west.
• Pah Canyon Tuff	--	0 - 70	Northward-thickening nonwelded to moderately welded tuff with pumice fragments.
• Topopah Spring Tuff	12.8	Maximum: 380	Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository.
Calico Hills Formation	12.9	15 - 460	Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain.
Crater Flat Group			Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite.
• Prow Pass Tuff	13.1	60 - 228	Sequence of variably welded pyroclastic deposits.
• Bullfrog Tuff	13.3	76 - 275	Partially welded, zeolytic upper and lower parts separated by a central densely welded tuff.
• Tram Tuff	13.5	60 - 396	Lower lithic-rich unit overlain by upper lithic-poor unit.
• Lithic Ridge Tuff	14.0	185 - 304	Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites.
Pre-Lithic Ridge	+14.0	180 - 345+	Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition.

a. Modified from TRW (1999h, pages 1-16 to 1-28).
b. To convert meters to feet, multiply by 3.208.
c. -- = no absolute dates.

development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and zeolite minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence. Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs. This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah Spring Tuff (the basal vitrophyre) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site. Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite erionite, which is a potential human health hazard (see Section 3.1.8). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DOE 1998a, Volume 1, page 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent such relatively quiet, nonexplosive eruptions of basaltic materials as lava flows and cinder cones. Examples include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a basalt ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 75,000 years old.

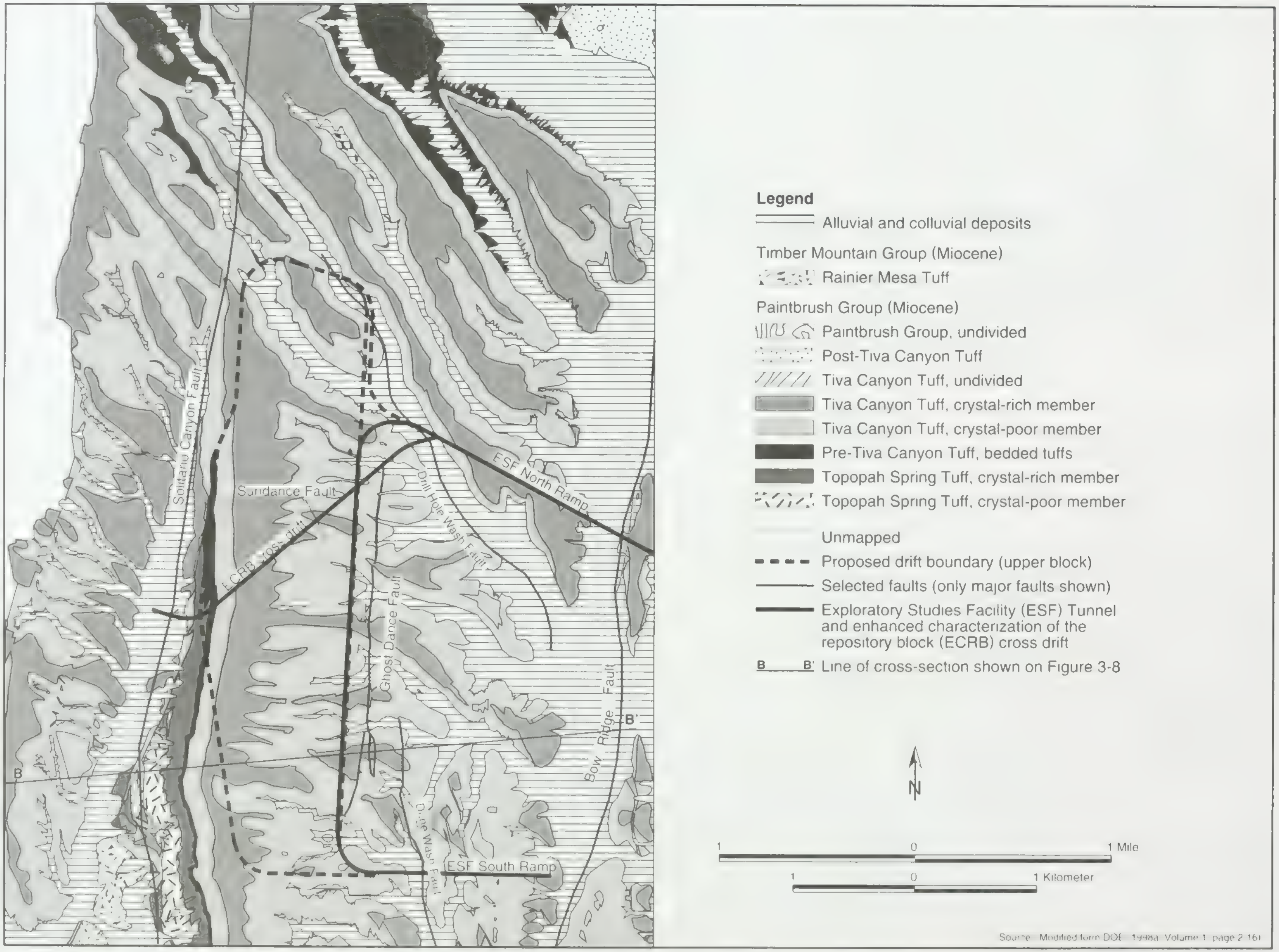


Figure 3-7. General bedrock geology of the proposed repository Central Block Area.

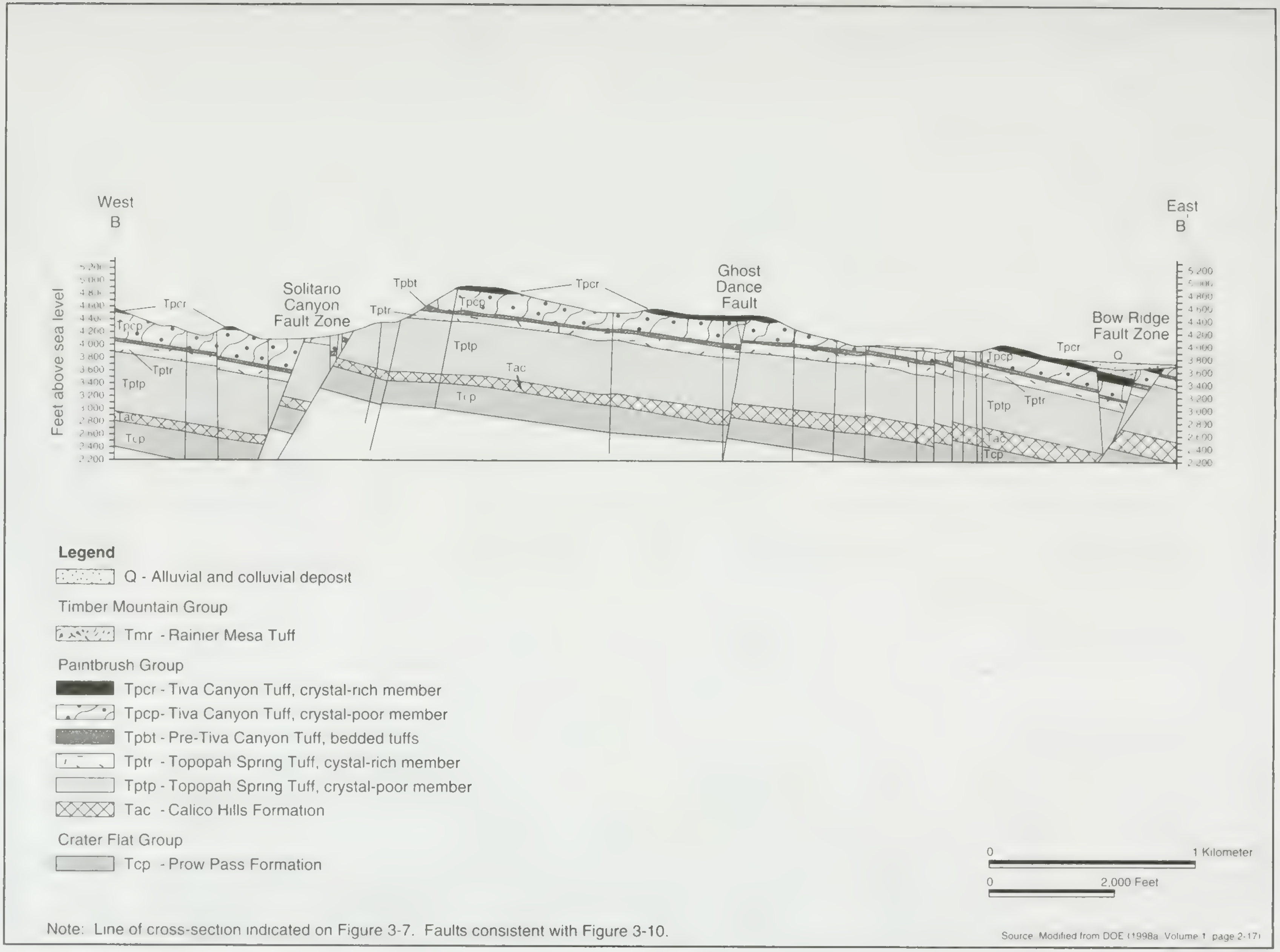


Figure 3-8. Simplified geologic cross-section of Yucca Mountain, west to east.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as alluvium (material such as sand, silt, or clay deposited on land by water) and colluvium (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (TRW 1998a, pages 3.4-1 to 3.4-33). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DOE 1998a, Volume 1, page 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

Selection of Repository Host Rock

Selection of the Topopah Spring tuff as the repository host rock was based on several considerations, which include (1) depth below the ground surface sufficient to protect nuclear waste from exposure to the environment, (2) extent and characteristics of the host rock, (3) location of faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of groundwater in relation to the proposed repository (TRW 1993, pages 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring tuff as the potential repository horizon. The rock is strongly welded with variable fracture density and void space; experience gained from the excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 100 meters (330 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 100 to 200 meters (330 to 660 feet) below the selected repository horizon (DOE 1998a, Volume 1, page 2-24). Section 3.1.4 discusses the water table level further.

Potential for Volcanism at the Yucca Mountain Site

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (see Chapter 5). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely.

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 75,000 years ago (TRW 1998a, pages 3.2-18 and 3.2-19). Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 75,000 years).

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). A panel of 10 scientists with expertise in volcanism reviewed the extensive information on volcanic

activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository.

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. In 1995 and 1996, DOE convened the panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey, national laboratories) and universities (for example, the University of Nevada and Stanford University) to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike) (Geomatrix and TRW 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000.

3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation to rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth's crust.

Major crustal compression occurred in the Great Basin between about 350 million and 50 million years ago, which resulted in older rocks being thrust over younger rocks for great distances (for example, thrust faults) to produce mountains. During the last 15 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins. Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (Scott and Bonk 1984, all; Day et al. 1996, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 15 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to as much as 600 meters (2,000 feet).

The total estimated displacement along the most active north-trending block-bounding faults in the Yucca Mountain region during the past 1.6 million years is less than 50 meters (165 feet) (Simonds et al. 1995, all). During the last 730,000 years the total displacement of north-trending block bounding faults has been as much as 6 meters (20 feet). However, during the past 128,000 years the typical total displacement has been about 1 to 2.5 meters (about 3.3 to 8 feet).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain is the major block-bounding fault. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults are many subsidiary northwest-trending faults with smaller displacements (Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10). In addition, there is one intrablock fault, called the Ghost Dance fault, in the area of

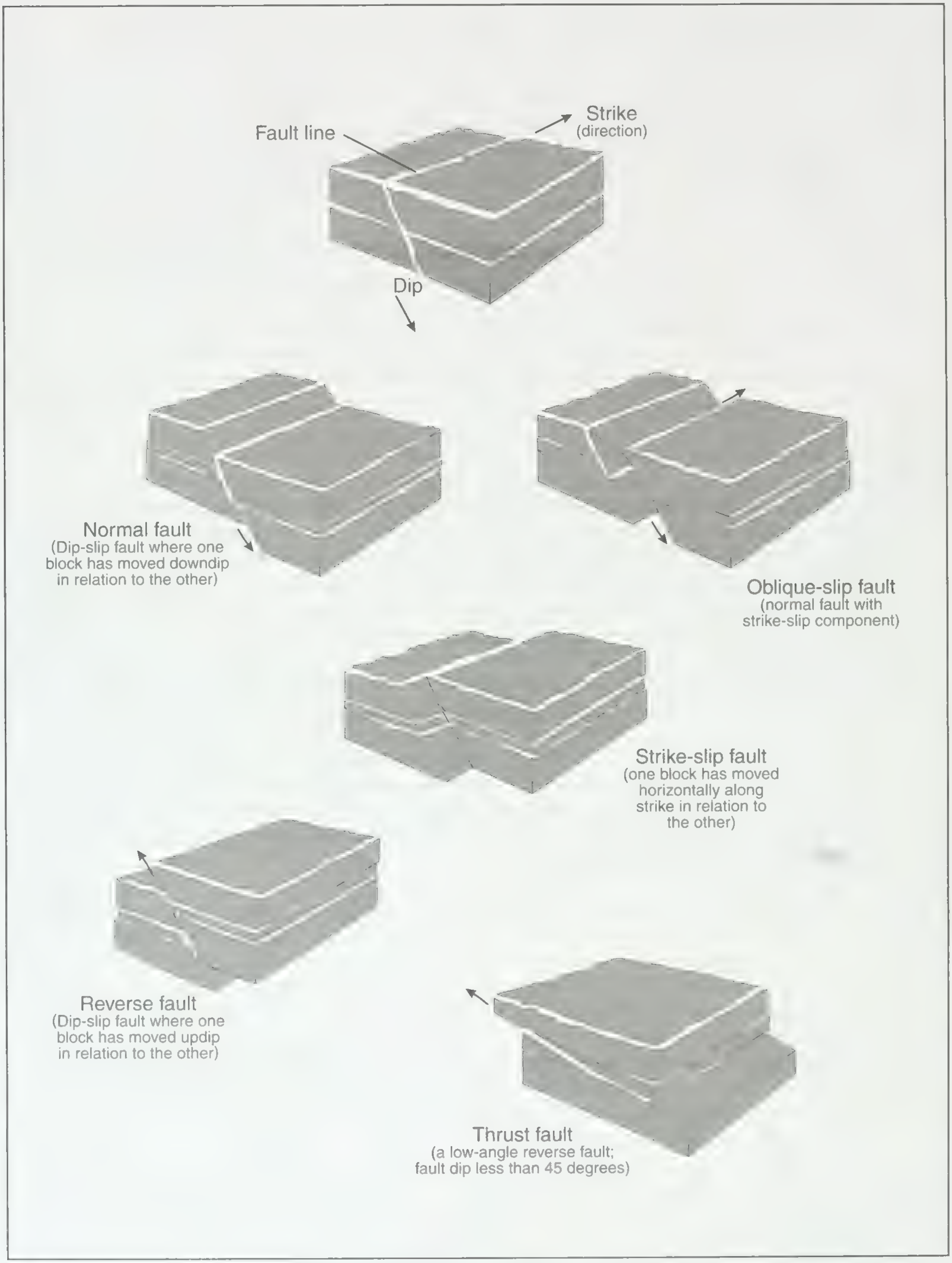


Figure 3-9. Types of geologic faults.

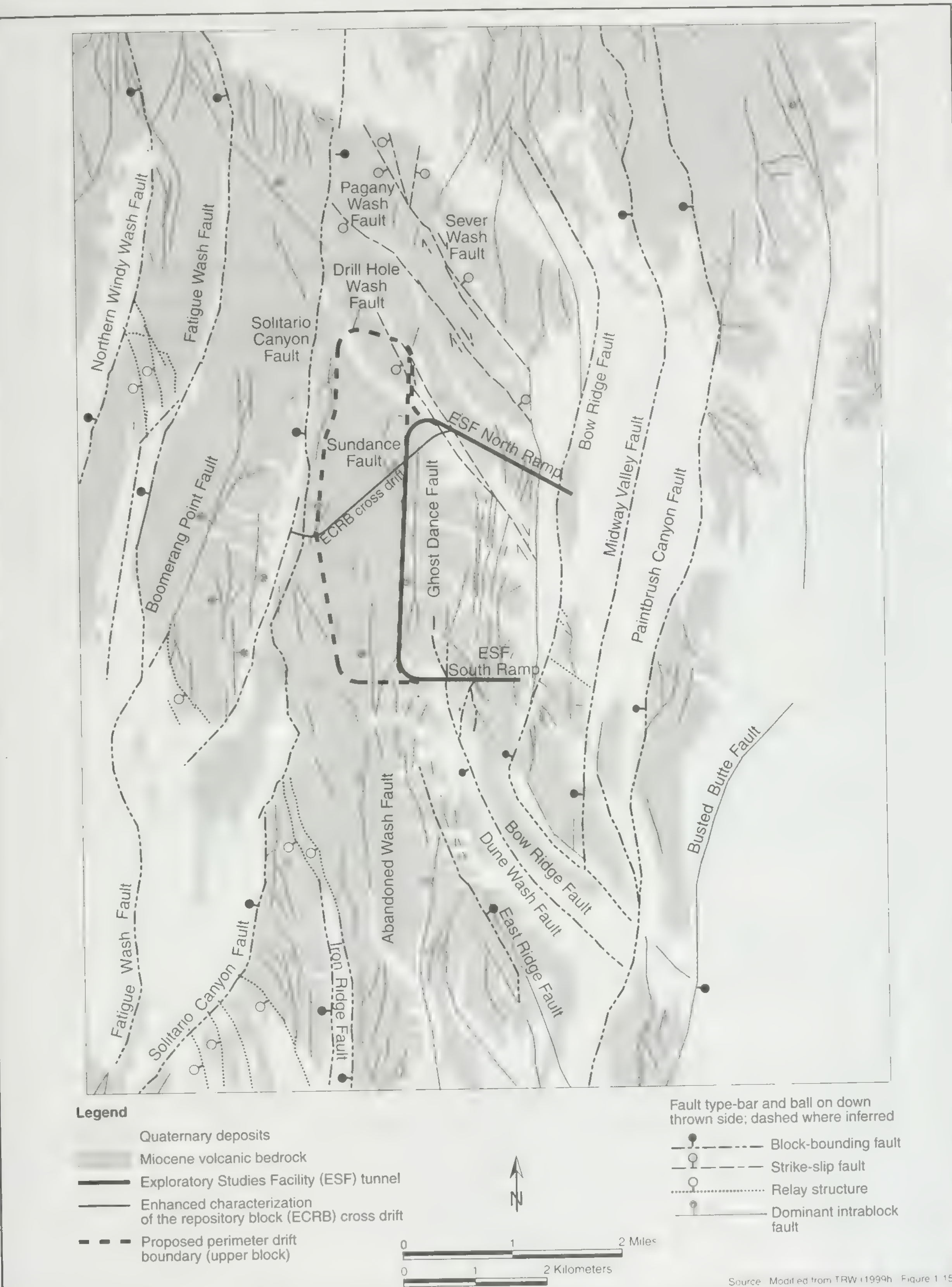


Figure 3-10. Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

Table 3-8. Characteristics of major faults at Yucca Mountain.[a]

Fault	Surface features	Evidence of late Quaternary displacement	Quaternary displacement (past 1.6 million years)	Total displacement; type of movement	Fault length (kilometers)[b] and dip
Windy Wash fault	East facing fault line scarps in alluvium, bedrock alluvium fault contacts; merges with Fatigue Wash fault	Two trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	1 meter[d] in late Quaternary; < 0.1 meter during past 10,000 years.	Increases southward to 500 meters; dip-slip, west side down.	3 - 25; 61° west.
Fatigue Wash fault	Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Fatigue Wash fault.	One trench shows multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	2.2 meters in late Quaternary.	72 meters; oblique left-lateral, west side down.	9.5 - 17; 71° west.
Solitario Canyon fault[c]	Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; merges with Stagecoach Road fault.	Nine trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	1.7 - 2.5 meters in late Quaternary.	Increases southward from 61 meters to > 500 meters; oblique left-lateral, down on east at north end, down on west at south end.	12.5 - > 21; 68° to 71° west.
Ghost Dance fault zone[e]	Bedrock fault in zone of subparallel minor faults and breccia zones.	None	None	Increases southward from 0 - 30 meters; dip-slip, west side down.	3 - 9; ~vertical.
Bow Ridge fault[c]	Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge with Paintbrush Canyon fault.	Five trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.5 - 1.3 meters in late Quaternary.	125 meters; oblique left-lateral, west side down.	0.8 - 107; 75° west.
Midway Valley fault[c]	None, fault located on basis of geophysical evidence.	None	None	40 - 60 meters; dip-slip, west side down.	1 - 8 ; west[f]
Paintbrush Canyon fault[c]	Bedrock and alluvial faults, scarps, and lineaments; possibly merges with Stagecoach Road fault.	Four trenches and exposures at Busted Butte show multiple ruptures; basalt ash in fault plane; fractures in alluvium.	1.7 - 2.7 meters (4.6 - 6.3 meters at Busted Butte in last 730,000 years).	250 - 300 meters; dip-slip and oblique left-lateral, west side down.	10 - > 26; 75° west.
Northwest-trending faults[g]	Bedrock faults with local scarps; most located by drilling and geophysical surveys.	None, with the exception of one trench across Pagany Wash fault showing possible Quaternary displacement.	None (see column to left).	40 meters right-lateral, 5 - 10 meters vertical.	2 - 8 per fault; > 70° south.

a Source: Modified from TRW (1999h, Table 1-2, pages 1-40 and 1-41).
b To convert kilometers to miles, multiply by 0.62137.
c Block-bounding fault.
d To convert meters to feet, multiply by 3.2808.
e Intrablock fault.
f The dip and direction of this fault are uncertain.
g Subsidiary faults (to be verified).

the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (TRW 1998a, page 3.6-24). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (TRW 1998a, Section 3.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults. This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 15 kilometers (9 miles). The earthquake focal mechanisms are strike-slip to normal oblique-slip along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992, which had a Richter magnitude of 5.6. This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively. Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities.

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DOE 1998a, Volume 1, pages 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (Kappes 1998, page VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 13-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by Savage et al. (1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed in 1998 (Savage, Svarc, and Prescott 1998, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by Wernicke et al. (1998, all).

DOE is continuing to monitor crustal strain in the Yucca Mountain region to determine if it can confirm the results of Wernicke et al. (1998, all). Through the University of Nevada, DOE is supporting continued monitoring by Dr. Wernicke. If the higher crustal strain rates are confirmed, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (Weiss, Noble, and Larson 1996, page 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent human intrusion (see Chapter 5). The *Yucca Mountain Site Description* (TRW 1998a, Section 3.11) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources. DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. Unless otherwise specified, the primary references for this section are the *Environmental Baseline File for Water Resources* (TRW 1999i, all) and the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all). Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DOE 1998a, Volume 1, page 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek Ranch sub-basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by evapotranspiration (Luckey et al. 1996, page 30). Important characteristics of the groundwater system include recharge zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

Evapotranspiration is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks permanent streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to the channel near Beatty, Nevada, south of Tecopa, California, and in southern Death Valley, California (TRW 1998a, page 5.1-4). The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (Bostic et al. 1997, pages 103 and 112), and its course extends roughly 90 kilometers (56 miles) farther before it ends in the Badwater Basin in Death Valley, which is more than 80 meters (260 feet) below sea level. The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe

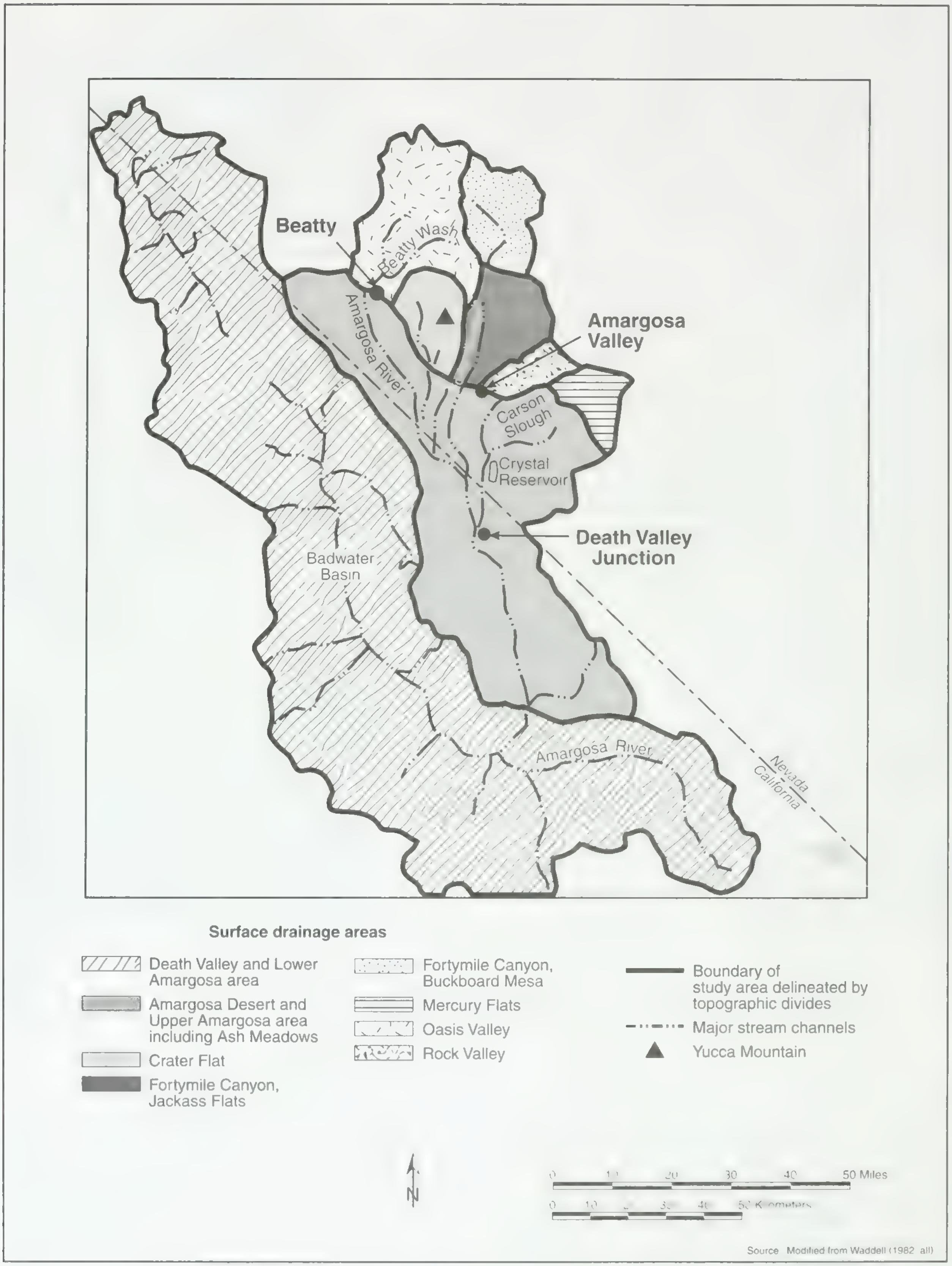


Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

Reservoir. The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (TRW 1998a, page 5.1-4).

3.1.4.1.2 *Yucca Mountain Surface Drainage*

Occurrence. No perennial streams, natural bodies of water, or naturally occurring wetlands occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River. In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost. Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain. Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation. When it occurs, intense flooding can include mud and debris flows in addition to water runoff (Blanton 1992, page 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, including an estimate for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (Blanton 1992, all; Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris, is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9. DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway

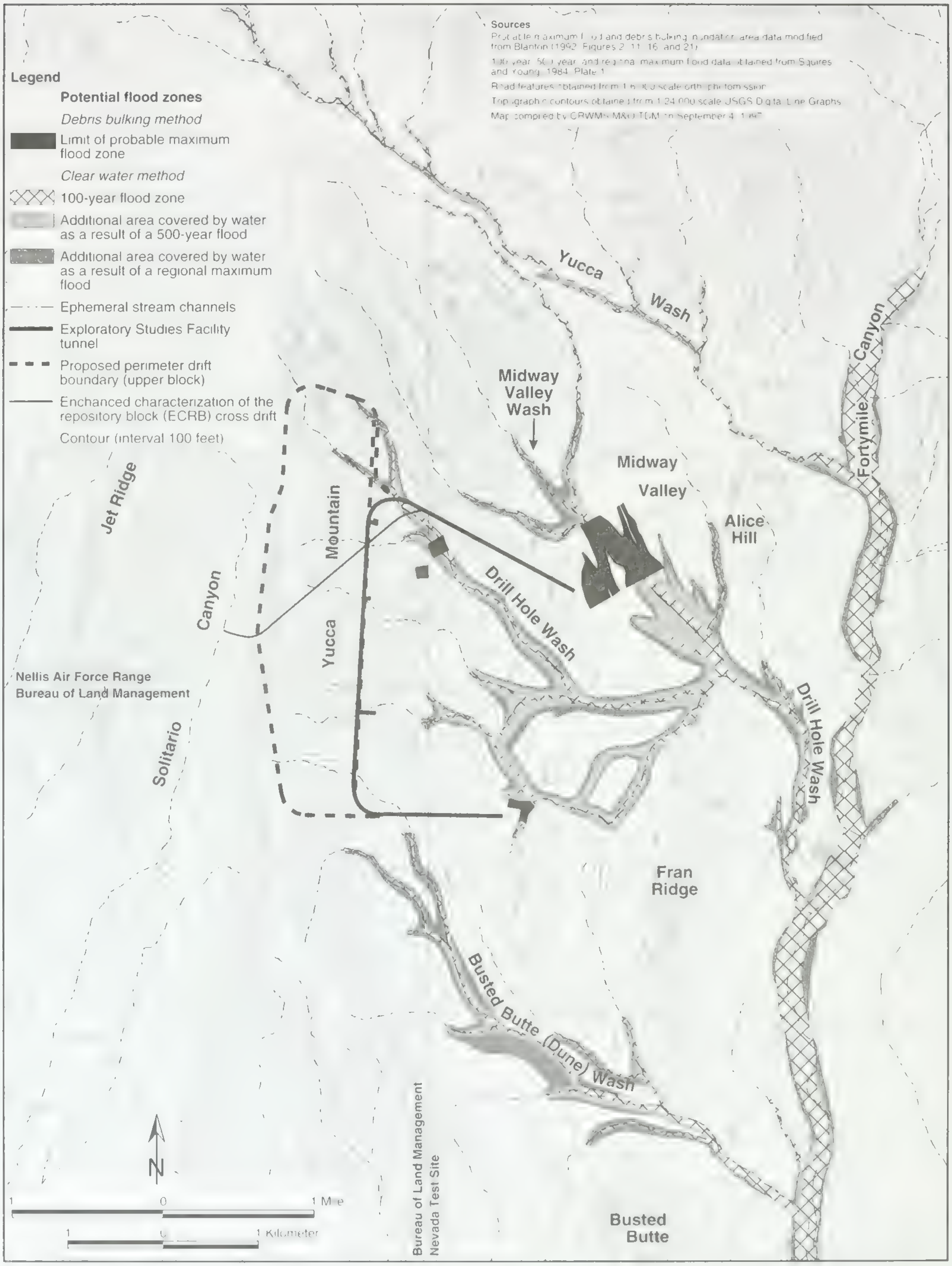


Figure 3-12. Site topography and potential flood areas.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.[a]

Name	Drainage area (square kilometers)[b]	Peak discharge 100-year flood (cubic meters per second)[c]	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash[d]	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: TRW (1999h, page 2-4).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and Coyote Washes as tributaries—North and South Portal Areas.

Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Along Busted Butte (Dune) and Drill Hole Washes, the 500-year flood would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. In no case, however, would flood levels reach either the North or South Portal opening to the subsurface facilities, which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a floodplain assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal

Table 3-10. Chemistry of surface water in the Yucca Mountain region.[a]

Chemical[b]	Range of chemical composition
pH	6.2 - 8.7
Total dissolved solids (milligrams per liter)	45.0 - 122
Calcium (milligrams per liter)	5.3 - 28.0
Magnesium (milligrams per liter)	0.2 - 4.0
Potassium (milligrams per liter)	3.0 - 11.0
Sodium (milligrams per liter)	2.4 - 46.0
Bicarbonate (milligrams per liter)	32.0 - 340.0
Chloride (milligrams per liter)	1.3 - 13.0
Sulfate (milligrams per liter)	2.8 - 26.0
Silica (milligrams per liter)	4.5 - 48.0

a. Source: TRW (1998a, Table 6.2-5a); TRW (1999h, page 2-8).
b. Based on samples from 15 different surface-water locations (12 involve a single sampling event, 2 involve two sampling events, and 1 involves three sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water.

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many aquifers and confining units. Over distance, these layers vary in their characteristics or even their presence. In some areas confining units allow considerable movement between aquifers; in other areas confining units are sufficiently impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley groundwater basin are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and

HYDROGEOLOGIC TERMS

Permeability: Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

Aquifer: A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

Confining unit (or aquitard): A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Inflow: Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

carbonate aquifers (TRW 1998a, pages 5.2-4 to 5.2-9). An alluvial aquifer is in a permeable body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of igneous (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north portion of the Death Valley hydrologic basin that includes the Yucca Mountain region is often underlain by volcanic rocks and associated volcanic aquifers. The basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (TRW 1998a, page 5.2-8). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from sub-basins to the north as well as from sub-basin areas to the east and, therefore, contain a mixture of water from several different aquifers. For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (Winograd and Thordarson 1975, page C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley. There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (Luckey et al. 1996, pages 32 and 40).

Basins. The Death Valley regional groundwater flow system, or basin, covers about 41,000 square kilometers (16,000 square miles) (Harrill, Gates, and Thomas 1988, sheet 1 of 2). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site. The major recharge areas are mountains in the east and north portions of the basin. The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat. Therefore, flow is primarily to the west or south.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (D'Agnese et al. 1997, page 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (TRW 1998a, pages 5.2-17 to 5.2-21). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-13). The area around Yucca Mountain is in the central portion of the regional groundwater basin, and this portion has three sub-basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek Ranch, and (3) Pahute Mesa-Oasis Valley (Rush 1970, pages 10 and 11; Waddell 1982, pages 13 to 20; Luckey et al. 1996, pages 28-30; and D'Agnese et al. 1997, page 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek Ranch sub-basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley.

The Ash Meadows sub-basin is the easternmost of the three sub-basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the sub-basin (D'Agnese et al. 1997, pages 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek Ranch sub-basin. The primary discharge point for this sub-basin is Ash Meadows, where springs occur in a line along a major fault. Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (Walker and Eakin 1963, page 24; D'Agnese et al. 1997, page 46).

The Pahute Mesa-Oasis Valley sub-basin includes the western portion of Pahute Mesa, Gold Flat, and Oasis Valley. Recharge comes primarily from the north at Black Mountain, Quartz Mountain, and Pahute Mesa, and along the Amargosa River and its tributaries. Subsurface outflow is into the Amargosa Desert

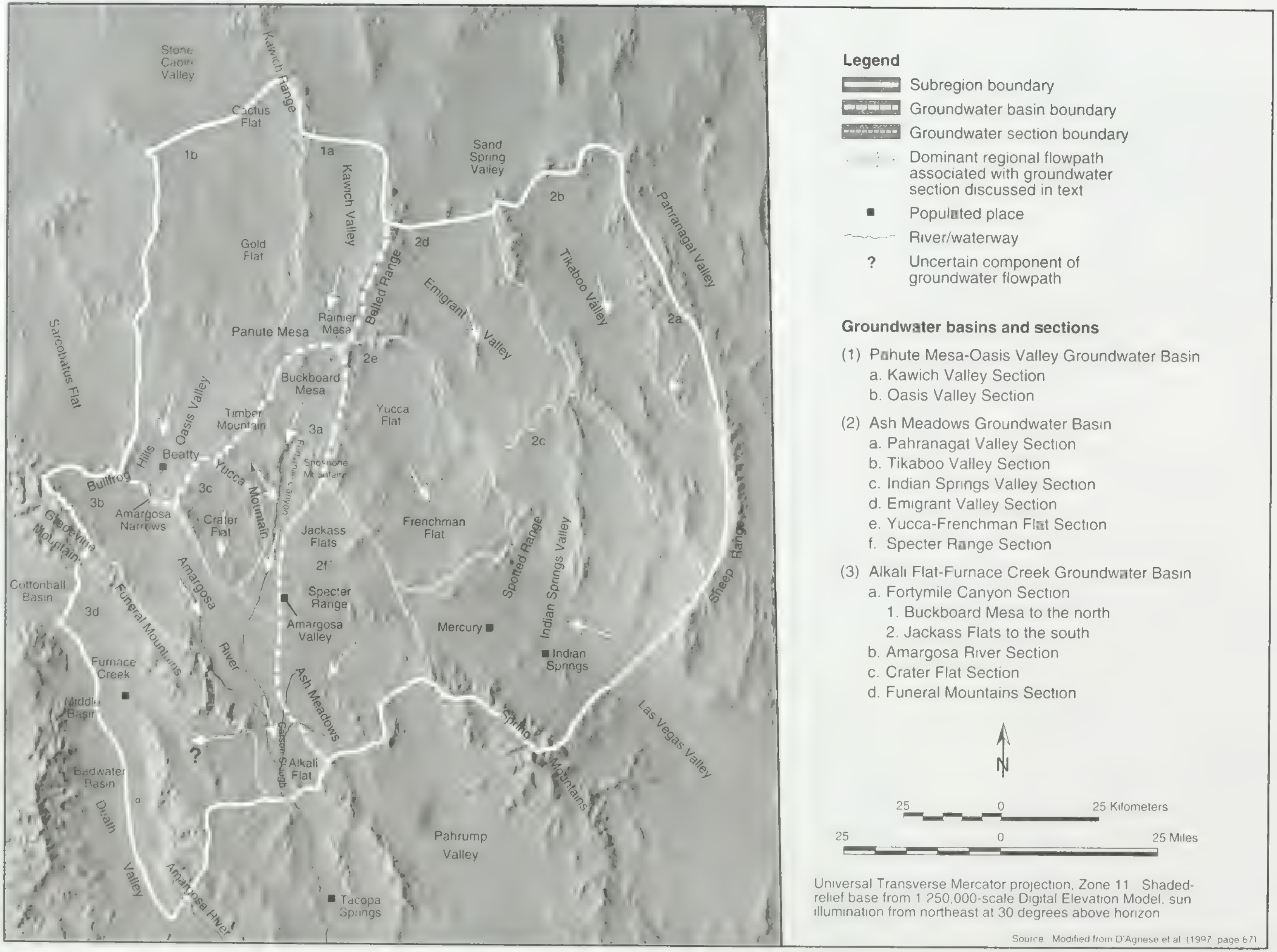


Figure 3-13. Groundwater basins and sections of the Central Death Valley subregion.

of the Alkali Flat-Furnace Creek Ranch sub-basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (Malmberg and Eakin 1962, page 26).

The Alkali Flat-Furnace Creek Ranch sub-basin is bordered on the northwest by the Pahute Mesa-Oasis Valley sub-basin and on the east by the Ash Meadows sub-basin. This sub-basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (D'Agnese et al. 1997, pages 67 to 69).

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the region that makes up the Alkali Flat-Furnace Creek Ranch sub-basin. The primary sources of surface recharge in this region are infiltration on Pahute Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south (D'Agnese et al. 1997, page 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 6.5 millimeters (0.3 inch) a year over the potential repository area for the current climate. This represents about 4 percent of an average annual precipitation rate of about 170 millimeters (7 inches) at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DOE 1997e, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Jackass Flats hydrographic area. From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley. There have been many estimates of the amount of groundwater moving along this path. One study (NDCNR 1971, page 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the Jackass Flats basin to the Amargosa Desert basin and 23.4 million cubic meters (19,000 acre-feet) from the Amargosa Desert basin to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) under the low thermal load, assuming 6.5 millimeters (0.3 inch) of infiltration per year, would be about 0.3 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

As water in the Alkali Flat-Furnace Creek Ranch sub-basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows sub-basin (DOE 1998a, Volume 1, pages 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows sub-basin provides much of the boundary between the two sub-basins. In this area there is a marked decline [about 37 meters (120 feet)] in water table elevation between Ash Meadows and the Amargosa Desert area to the west and south (Dudley and Larson 1976, page 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek Ranch sub-basin, rather than the opposite. The primary groundwater discharge point for this sub-basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley.

Different researchers have speculated that the general flow boundaries of the three sub-basins in the Central Death Valley groundwater basin are in slightly different locations (D'Agnese et al. 1997, page 59). Some studies [for example, Waddell (1982, page 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek Ranch sub-basin rather than in the Pahute Mesa-Oasis Valley sub-basin as

shown in Figure 3-13. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the sub-basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek Ranch sub-basin.

Use. Table 3-11 summarizes groundwater use in the Yucca Mountain region. The hydrographic areas listed in the table are basically a finer division of the basins and sub-basins discussed above; their locations are consistent with the hydrographic areas shown in Figure 3-13. DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek sub-basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer. Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes. As Table 3-11 indicates, water use averaged about 17.5 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn. The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (Cappaert v. United States 1976, all) to protect the water level in Devils Hole.

Table 3-11. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c] (acre-feet per year)[d]	Current appropriations[e,c] (acre-feet per year)	Average annual withdrawals 1995-1997 (acre-feet)	Chief uses
Jackass Flats (Area 227a)	880[f] - 4,000	500[g]	340[h]	Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain.
Crater Flat (Area 229)	220 - 1,000	1,200[i]	140[j]	Mining, site characterization of Yucca Mountain
Amargosa Desert (Area 230)	24,000 - 34,000	27,000	14,000[j]	Agriculture, mining, livestock, municipal, wildlife habitat
Oasis Valley (Area 228)	1,000 - 2,000	1,700	N/A[k]	Agriculture, municipal

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-17.
b. An estimate of the quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Sources: Thiel (1997, pages 5-12); perennial yield values only, DOE (1996f, pages 4-117 and 4-118).
d. An acre-foot is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: Bauer et al. (1996, page 702) and Bostic et al. (1997, page 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: La Camera, Westenburg, and Locke (1996, page 74) and La Camera and Locke (1997, page 77).
k. N/A = not available.

Table 3-11 lists water volumes (perennial yield, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

Groundwater Quality. The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples. A recent sampling effort (Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek Ranch sub-basin and the Ash Meadows sub-basin.

> **ENVIRONMENTAL PROTECTION AGENCY DRINKING WATER QUALITY STANDARDS**
>
> **Primary standards** are health-based and enforceable for all public drinking water supply systems (including the existing system at the site of the proposed repository).
>
> **Secondary standards** control substances that primarily affect aesthetic qualities (such as taste, odor, and color). They are not Federally enforceable and, if exceeded, would generally not cause health problems.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 USC 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (NDWP 1999a, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, pages 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

Unsaturated Zone

Water Occurrence. The unsaturated zone at Yucca Mountain extends down from the crest of the mountain 500 to 750 meters (about 1,600 to 2,500 feet) to the water table (the upper surface of the saturated zone). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, between about 175 and 365 meters (570 and 1,200 feet) above the present water table. The excavation of the Exploratory Studies Facility encountered very limited quantities of water, and no dripping water or water in sufficient quantities to collect. Some moist areas were observed during excavations through the Paintbrush nonwelded tuff (Figure 3-14) (Peters 1999, all). Boreholes in the

> **SUBSURFACE FORMATIONS CONTAINING WATER**
>
> **Unsaturated zone:** The zone of soil or rock between the land surface and the *water table.*
>
> **Saturated zone:** The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater.*
>
> **Perched water bodies:** Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of perched water (Figure 3-14). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone. Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon (TRW 1998a, page 5.3-236) near the base of the Topopah Spring welded tuff unit (Figure 3-14). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating indicates this recharge occurred during the past 6,000 years. Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the general conclusion is that the perched water is much too recent to indicate large contributions from pore water in the rock matrix. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection.

Hydrologic Properties of Rock. The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented materials called tuffs that have varying degrees of welding. The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures. Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

> **TYPES OF TUFF**
>
> **Welded tuff** results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.
>
> **Non-welded tuff** results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a single stratigraphic unit (such as tuff flow) might have been generated by an igneous or volcanic flow. Because of different cooling rates at different depths, a single volcanic flow unit might have layers with different degrees of welding that cause water to move at different rates. The result of this example is a single stratigraphic

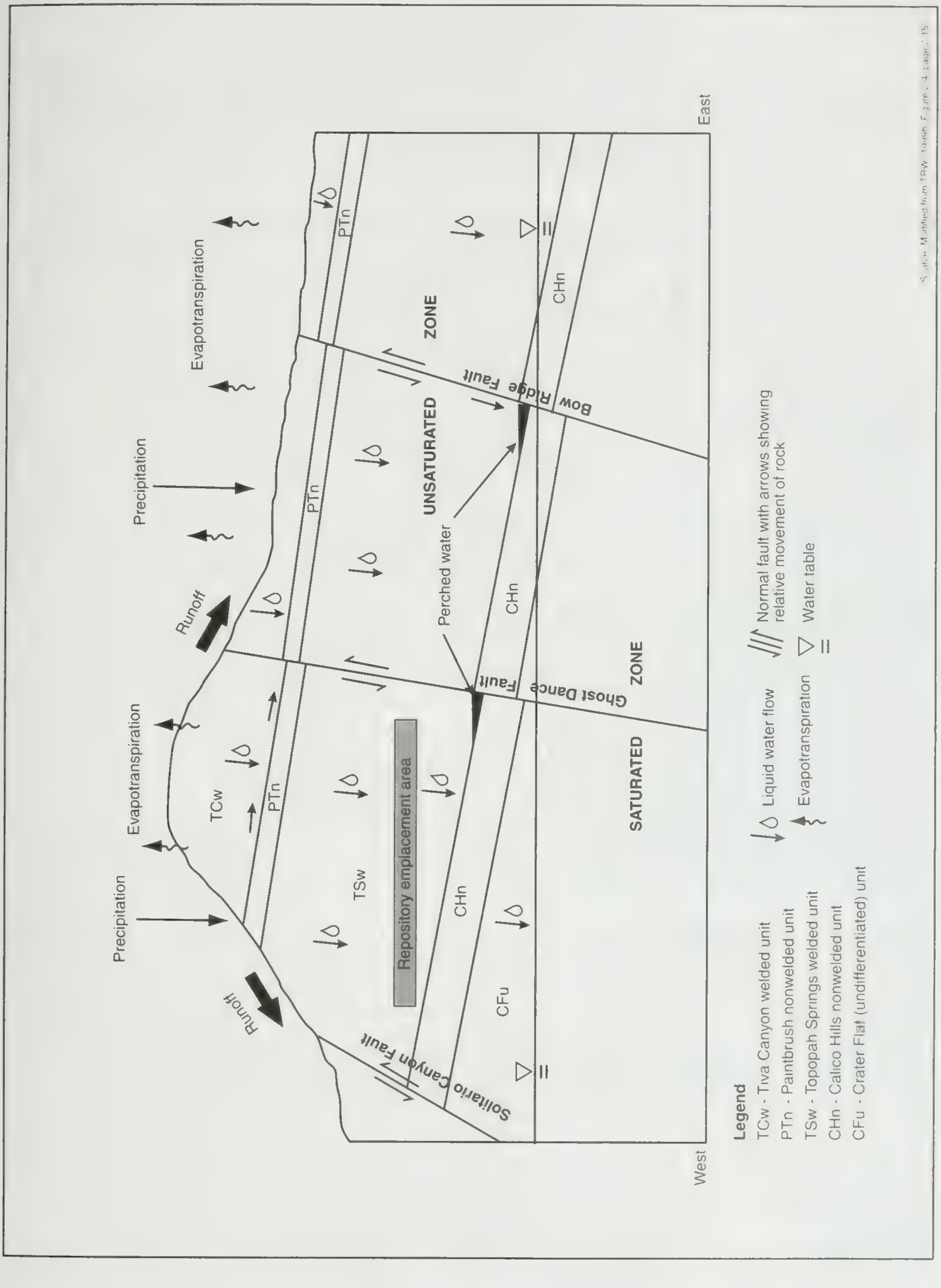


Figure 3-14. Conceptual model of water flow at Yucca Mountain.

unit that includes more than one hydrogeologic unit. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-15 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area's groundwater system. Table 3-12 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

Table 3-12. Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

Unit and characteristics[b]	Thickness (meters)[c]
Quaternary alluvium/colluvium Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high.	0 - 30
Tiva Canyon welded unit (TCw) Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 50 to 80 percent.	0 - 150
Paintbrush nonwelded unit (PTn) Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 60 percent; matrix saturation, 30 to 60 percent.	20 - 100
Topopah Spring welded unit (TSw) Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 40 percent, commonly greater than 80 percent.	290 - 360
Calico Hills nonwelded unit (CHn) Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity variable, 10 to 40 percent; matrix saturation 20 to 90 percent, commonly near 100 percent in zeolitic zones.	100 - 400
Crater Flat undifferentiated unit (CFu) Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation.	0 - 200

a. Source: TRW (1999h, pages 2-12 and 2-13).
b. Letters in parentheses are used in Figures 3-14 and 3-15.
c. To convert meters to feet, multiply by 3.2808.

Water Source and Movement. When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration. Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 4.5 millimeters (0.2 inch) per year in a study area of about 230 square kilometers (89 square miles) that includes Yucca Mountain and 6.5 millimeters (0.3 inch) per year in the potential repository area (Flint, Hevesi, and Flint 1996, page 91). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock. On a year-to-year basis, the average net infiltration can range from 0 to 2 centimeters (0.8 inch).

Era	Geologic Age	Stratigraphic unit	Approximate range of thickness (meters)	Hydrogelogic units: Unsaturated	Hydrogelogic units: Saturated	Comments
Cenozoic Era	Quaternary and Tertiary Periods	Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits	0-30	QAL, alluvium	QTa, Valley-fill aquifer; QTc, valley-fill confining unit	QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source
	Tertiary Period	Timber Mountain Group Rainier Mesa Tuff				Minor erosional remnants at Yucca Mountain
		Paintbrush Group Tiva Canyon Tuff	0-150	TCw Tiva canyon welded unit		Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain
		(bedded tuff) Yucca Mountain Tuff Pah Canyon Tuff	20-100	PTn Paintbrush nonwelded unit		Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff.
		Topopah Spring Tuff (vitrophyre and non-welded tuffs at base)	290-360	TSw Topopah Spring welded unit	uva, Upper volcanic	About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site
		Calico Hills Formation	100-400	CHn Calico Hills nonwelded unit	uvc, Upper volcanic confining unit	Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table
		Crater Flat Group Prow Pass Tuff Bullfrog Tuff Tram Tuff	0-200	CFu Crater Flat undifferentiated unit	mva Middle volcanic aquifer units	Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas commonly zeolitized; most permeable zones are fracture-controlled
		Unnamed flow breccia Lithic Ridge Tuff	1,000-2,000		mvc, Middle volcanic confining unit	Nonwelded tuff, pervasively zeolitized
		Volcanics of Big Dome			lva, Lower volcanic aquifer	Lava flows and welded tuff; not known at Yucca Mountain
	(Lower Tertiary?)	Older volcanics			lvc, Lower volcanic confining unit	Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part
Paleozoic Era	Permian/ Pennsylvanian Periods	Bird Spring Formation Tippipah Limestone	1,000 ±		uca, Upper carbonate aquifer	Limited distribution in saturated zone north and east of Yucca Mountain
	Mississipian/ Devonian Periods	Eleana Formation (Chainman Shale)	2,500 ±		ecu, Eleana confining unit	Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain
	Devonian Silurian Ordovician Cambrian Periods	Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation	7,500 ±		lca, Lower carbonate aquifer	Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick
		Lower Carrara Formation			zcu, Precambrian confining unit	Dolomite, shale
Proterozoic	(Upper Precambrian)	Proterozoic rocks				Quartzite, slate, marble; fractures commonly healed by mineralization

Source. Modified from TRW (1999h, Figure 2-3, pages 2-10 and 2-11)

Figure 3-15. Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures. Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone.

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties. Water that infiltrates into the Tiva Canyon welded unit can often be transported as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

CHLORINE-36 STUDIES

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (Levy et al. 1997, page 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

DOE has used the ratio of chlorine-36 (a naturally occurring isotope) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel. About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)].

Most of the samples (87 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 50,000 years or more. Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water (TRW 1998a, page 5.3-176). Further, the data indicate that, away from fault zones, travel times to the repository horizon correlate with the thickness of the overlying nonwelded Paintbrush unit. The shortest travel times (less than 10,000 years) occur in the southern part of the Exploratory Studies Facility where the unit is thinnest.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (TRW 1998a, page 5.3-176). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (Fabryka-Martin et al. 1998, page 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-14 and Table 3-12). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of percolation through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected. Below the repository level, low-permeability zeolite zones impede the vertical flow of water near the Topopah Spring welded unit and its contact with the underlying Calico Hills nonwelded unit, forming perched water bodies. The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain, perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-14). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below. This is consistent with the concept that some of the water moves laterally on top of the zeolite zone before it resumes its downward course to the saturated zone.

Unsaturated Zone Groundwater Quality. DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-13 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

Table 3-13. Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

Constituent	Ranges of chemical composition	
	Perched	Pore
pH	7.6 - 8.7	7.7 - 8.4
Total dissolved solids (milligrams per liter)	140 - 330	320 - 360
Calcium (milligrams per liter)	2.9 - 45	1.1 - 62
Magnesium (milligrams per liter)	0 - 4.1	0 - 4.5
Potassium (milligrams per liter)	1.7 - 10	N/A[b]
Sodium (milligrams per liter)	34 - 98	49 - 140
Bicarbonate (milligrams per liter)	110 - 220	170 - 230
Chloride (milligrams per liter)	4.1 - 16	26 - 90
Bromide (milligrams per liter)	0 - 0.41	0
Nitrate (milligrams per liter)	0 - 34	11 - 17
Sulfate (milligrams per liter)	4 - 220	14 - 45

a. Source: Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water.

Saturated Zone

Water Occurrence. The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-15). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the Calico Hills nonwelded unit and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-15. The lower volcanic aquifer in Figure 3-15 has not been identified in the area of the proposed repository.)

South of the proposed repository site, downstream in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (TRW 1998a, page 5.3-7). In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits.

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon. This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow. Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) and, similarly, was recharged during

a wetter and cooler climate. Some of the limited carbonate aquifer sample results indicate older water ages (30,000 years and greater), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of "dead carbon" (nonradioactive) dissolved from the carbonate rock. Limited data show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers. This indicates that, in the vicinity of Yucca Mountain, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified six wetter and cooler periods in the southern Great Basin during late Pleistocene time. These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 260,000 years ago; 330,000 to 400,000 years ago; and 430,000 to 470,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (TRW 1998a, page 4.2-24). During the wetter periods, the elevation of the saturated zone was as much as about 100 meters (330 feet) higher than it is today. The repository would be above this historic maximum elevation (see Section 2.1). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old. The *Yucca Mountain Site Description* (TRW 1998a, pages 4.2-1 to 4.2-41) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

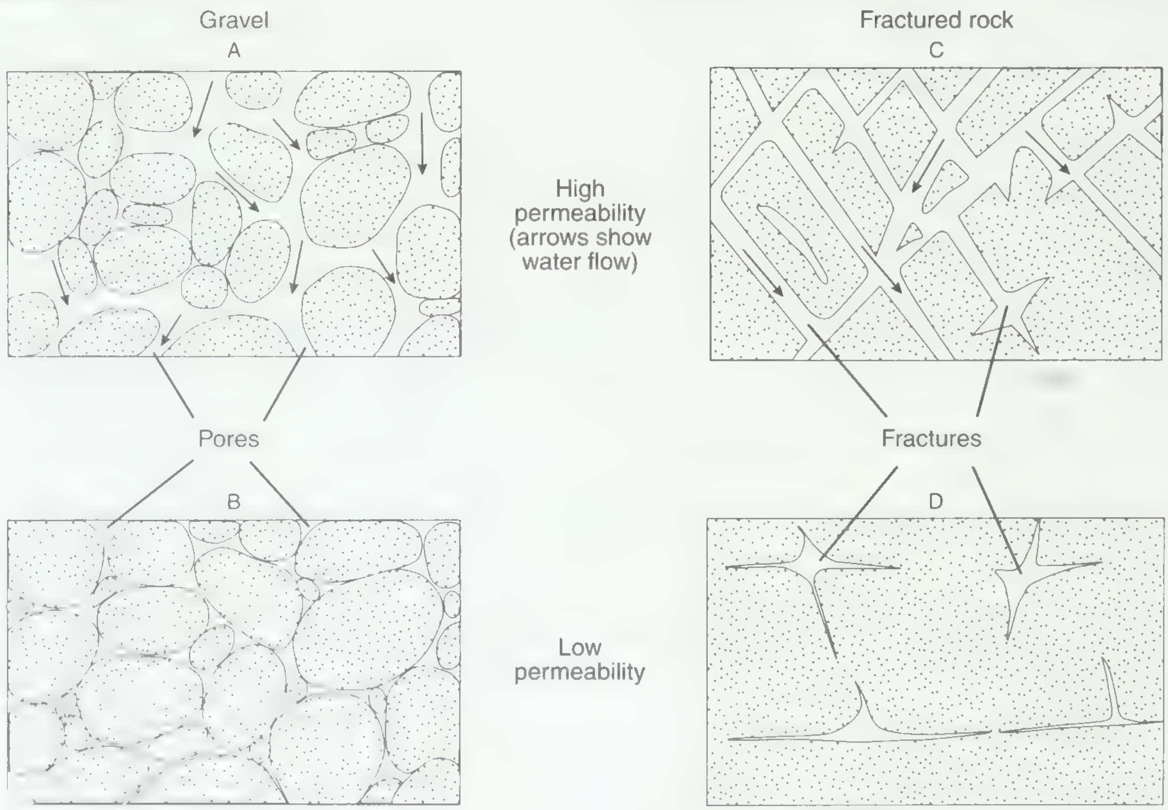
Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 100 meters (330 feet) above the current level, even reaching the land surface in the past (Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (TRW 1998a, page 3.4-20). Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (Luckey et al. 1996, pages 76-77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DOE 1998a, Volume 1, page 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (TRW 1998a, page 3.4-29).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent

experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE has disagreed with some of the central scientific conclusions presented in this report, both parties have agreed that additional research is needed to resolve the issues. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

Hydrologic Properties of Rock. This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-16 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size



A. Gravel with interconnected pore space having relatively high permeability.
B. Gravel with limited interconnected pore space having relatively low permeability.
C. Rock with interconnected fractures having relatively high permeability.
D. Rock with few interconnected fractures having relatively low permeability.

Source: Modified from USGS 1993, page 2

Figure 3-16. Aquifer porosity and effects on permeability.

or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures. Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-14, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

Table 3-14. Aquifers and confining units in the saturated zone at Yucca Mountain.

Unit	Typical thickness (meters)[a,b,c]	Transmissivity (square meters per day)[d,e]	Apparent hydraulic conductivity (meters per year)[e]	Porosity[f,g] (ratio)
Upper volcanic aquifer Densely welded and densely fractured part of Topopah Spring Tuff	300	120 - 1,600	47 - 6,900	0.036 - 0.16
Upper volcanic confining unit Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff	90 - 330	2.0 - 26	7.3 - 95	0.17 - 0.35 (Calico Hills)
Lower volcanic aquifer Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group	370 - 700	1.1 - 3,200	< 1.4 - 4,700	0.26 - 0.33 (Prow Pass Tuff) 0.12 - 0.26 (Bullfrog Tuff)
Lower volcanic confining unit Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff	370 - > 750	0.003 - 23	0.002 - 40.2	N/A[h]
Lower carbonate aquifer Cambrian through Devonian limestone and dolomite	N/A	120	69	N/A

a. Source: Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: TRW (1998a, Tables 5.3-35 and 5.3-36).
f. Source: TRW (1999h, Table 2-2, page 2-40).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

Water Source and Movement. Section 3.1.4.2.1 describes the direction of water movement (Figure 3-13), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable, with long-term measurements generally varying less than 0.1 meter (0.3 foot) since 1983. These small variations are probably due to changes in barometric pressure and Earth tides. In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 2.2 meters (7 feet) in response to earthquake events, but the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours. An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months. At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of 2.5 kilometers (1.6 miles). Experts reviewing the data have suggested several credible reasons for this steep gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (Geomatrix and TRW 1998, pages 3-5 and 3-6). However, there are no obvious geologic reasons for the steep gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 20 meters (66 feet) in 0.4 kilometer (0.25 mile), while east of the fault the water table slopes very gently. West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, Davies and Archambeau (1997, pages 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (Geomatrix and TRW 1998, page 3-14).

Inflow to Volcanic Aquifers at Yucca Mountain. There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source are not known.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-13) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate. From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (Benson and McKinley 1985, page 4).

The estimated annual recharge along the 150-kilometer (93-mile) length of Fortymile Wash averages about 4.22 million cubic meters (3,400 acre-feet). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After several periods of flow in Fortymile Wash during 1992 and 1993, water levels in nearby wells rose substantially. Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring. Paleoclimatic evidence suggests that a perennial stream might have existed in Fortymile Wash 25,000 to 50,000 years ago, and that substantial recharge might have occurred as recently as 15,000 years ago.

Recharge to the saturated zone below Yucca Mountain from precipitation is probably small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.5 millimeters (0.2 inch) over a 220-square-kilometer (85-square-mile) vicinity around Yucca Mountain would produce a quantity of recharge less than one quarter of the estimated annual recharge along Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

Outflow from Volcanic Aquifers at and Near Yucca Mountain. Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 80 kilometers (50 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley groundwater basin (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Valley.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the

carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

Use. Two wells, J-12 and J-13 (shown in Figure 3-17), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Operations Area (Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (Luckey et al. 1996, page 70).

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as F-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet). The permit limits apply to site characterization water use. Table 3-15 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-15 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (La Camera and Locke 1997, pages 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-16 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

The elevation changes listed in Table 3-16 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in

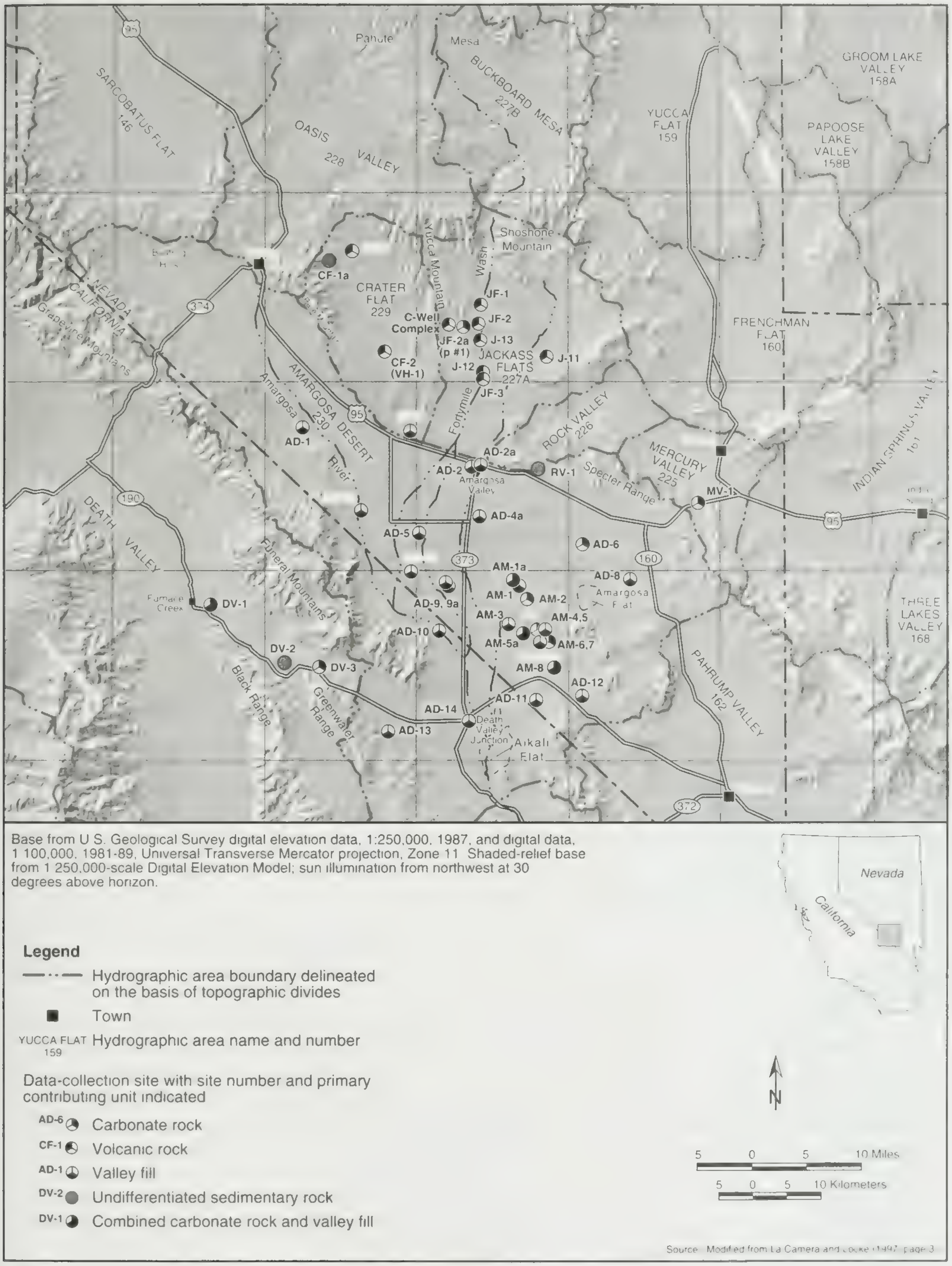


Figure 3-17. Selected groundwater data-collection sites in the Yucca Mountain region.

Table 3-15. Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

Year	J-12 and J-13 Yucca Mountain characterization[b]	J-12 and J-13 total withdrawals[c]	C-wells[b]
1992	18	120	0
1993	80	210	0
1994	75	280	0
1995	94	260	19
1996	66	220	180
1997	63	150	190
1998	63[d]	N/A[e]	190[f]
1999	63	N/A	N/A
2005	63	N/A	N/A

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: TRW (1999j, page 4).
c. Source: Clary et al. (1995, page 660); Bauer et al. (1996, page 702); Bostic et al. (1997, page 592); Bonner et al. (1998, page 606); La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in La Camera and Locke (1997, page 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

Table 3-16. Differences between annual median elevations and baseline median elevations.[a]

	Baseline elevations		Difference (in centimeters[b]) baseline					
Well	Median (meters[c] above sea level)	Average deviation about the median (centimeters)	1992	1993	1994	1995	1996	1997
JF-1	729.23	± 6	−3	0	−6	0	−6	−3
JF-2	729.11	± 9	+3	0	+3	+9	0	−3
JF-2a[d]	752.43	± 12	0	+6	+12	+15	+21	+27
J-13	728.47	± 6	−3	−3	−9	−6	−12	−12
J-11	732.19	± 3	0	0	+3	+6	+6	+12
J-12	727.95	± 3	0	0	−3	−3	−9	−9
JF-3	727.95	± 3	N/A[e]	N/A	−6	−6	−9	−9

a. Source: La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.

- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).

- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (La Camera and Locke 1997, page 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Five of these wells (see Figure 3-17) are in or very close to Fortymile Wash and the two wells (JF-2a and J-11) that are farthest from the wash are those wells that have shown a water level increase.

Table 3-17. Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

Chemical constituent	Chemical composition	
	Volcanic aquifers[b]	Lower carbonate aquifer[c]
Calcium	1 - 20	100
Magnesium	0.01 - 2	39
Potassium	1 - 5	12
Sodium	38 - 100	150
Bicarbonate	110 - 280	570
Chloride	5 - 10	28
Sulfate	40 - 57	160
Silica	40 - 57	41

a. Source: TRW (1999h, pages 2-43 to 2-44).
b. Based on samples from 12 wells.
c. Based on samples from one well.

Saturated Zone Groundwater Quality. Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride, as was a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the dissolution of volcanic tuff (Table 3-17). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-17).

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (TRW 1998b, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-18 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-17, the contributing aquifer, and a comparison, if applicable, to Maximum Contaminant Levels established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek sub-basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows sub-basin and Crystal Pool and Fairbanks Spring are on the border between the two sub-basins, but are fed by flow

Table 3-18. Results of 1997 groundwater sampling and analysis for radioactivity.[a]

Site name and location description[b]	Contributing aquifer	Average combined radium-226 and -228 (picocuries per liter)	Average gross alpha (picocuries per liter)	Average total uranium[c] (micrograms per liter)	Average gross beta (picocuries per liter)
J-12 Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.18±0.31	BDL[d]	0.52±0.05	6.23±0.86
J-13 Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.45±0.36	BDL	0.51±0.04	5.84±0.85
C-3 (C-well complex) By South Portal, SE of Yucca Mtn.	Volcanic	0.58±0.36	1.34±1.05	1.04±0.09	3.59±0.76
Crystal Pool (Spring) (AM-5a) Ash Meadows	Carbonate/ alluvial[e]	0.93±0.20	BDL	2.64±0.23	14.0±1.28
Fairbanks Spring (AM-1a) Ash Meadows	Carbonate/ alluvial	0.80±0.36	BDL	2.23±0.19	11.1±1.17
Nevada Department of Transportation Well (AD-2a) Amargosa Valley	Alluvial	0.32±0.33	BDL	2.55±0.22	5.95±0.93
Gilgans South Well (AD-9a) Amargosa Desert	Alluvial	0.19±0.31	BDL	0.63 ± 0.05	9.14±0.97
Cherry Patch Well (AD-8) NE of Ash Meadows	Alluvial	0.22±0.33	9.19±4.35	13.1 ± 1.16	18.7±1.65
Drinking water Maximum Contaminant Levels[f]		5	15	NA[g]	NA

a. Source: TRW (1998b, pages 12 to 21).
b. Figure 3-18 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (TRW 1998b, page 15).
d. BDL = below detection limit.
e. Alluvium is identified as valley fill in TRW (1999h, pages 1-7 and 1-8).
f. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
g. NA = not applicable.

through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-18 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (TRW 1998b, pages 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (TRW 1998b, page 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (TRW 1998b, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DOE 1996f, pages 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from

one below-groundwater test at Pahute Mesa. Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (Kersting et al. 1999, page 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-17). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life of the repository. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system under the repository.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all) or the *Environmental Baseline File for Soils* (TRW 1999l, all).

The State of Nevada (NWPO 1997, all) has expressed the opposing view that there was no systematic, interdisciplinary, environmental program before investigations began in 1982 to characterize the unique and fragile desert environment at Yucca Mountain before potential irreversible alterations (Lemons and Malone 1989, pages 435 to 441). However, after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (Lemons and Malone 1989, pages 435 to 441), and established an environmental baseline from these data for use in the preparation of the EIS (Malone 1989, pages 77 to 95). Many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals (Malone 1995, pages 271 to 284), did not use an integrated ecosystem approach and, therefore, are of little value for evaluating impacts of the repository.

Studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities during repository construction and operation (for example, habitat destruction).

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

Broad categories of land cover types (based primarily on predominant vegetation) have been identified and mapped across the State of Nevada (Utah State University 1996, GAP Data) and at the site of the proposed Yucca Mountain Repository (TRW 1998c, page 9). Land cover types typical of the Mojave and

Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent) (Figure 3-18). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

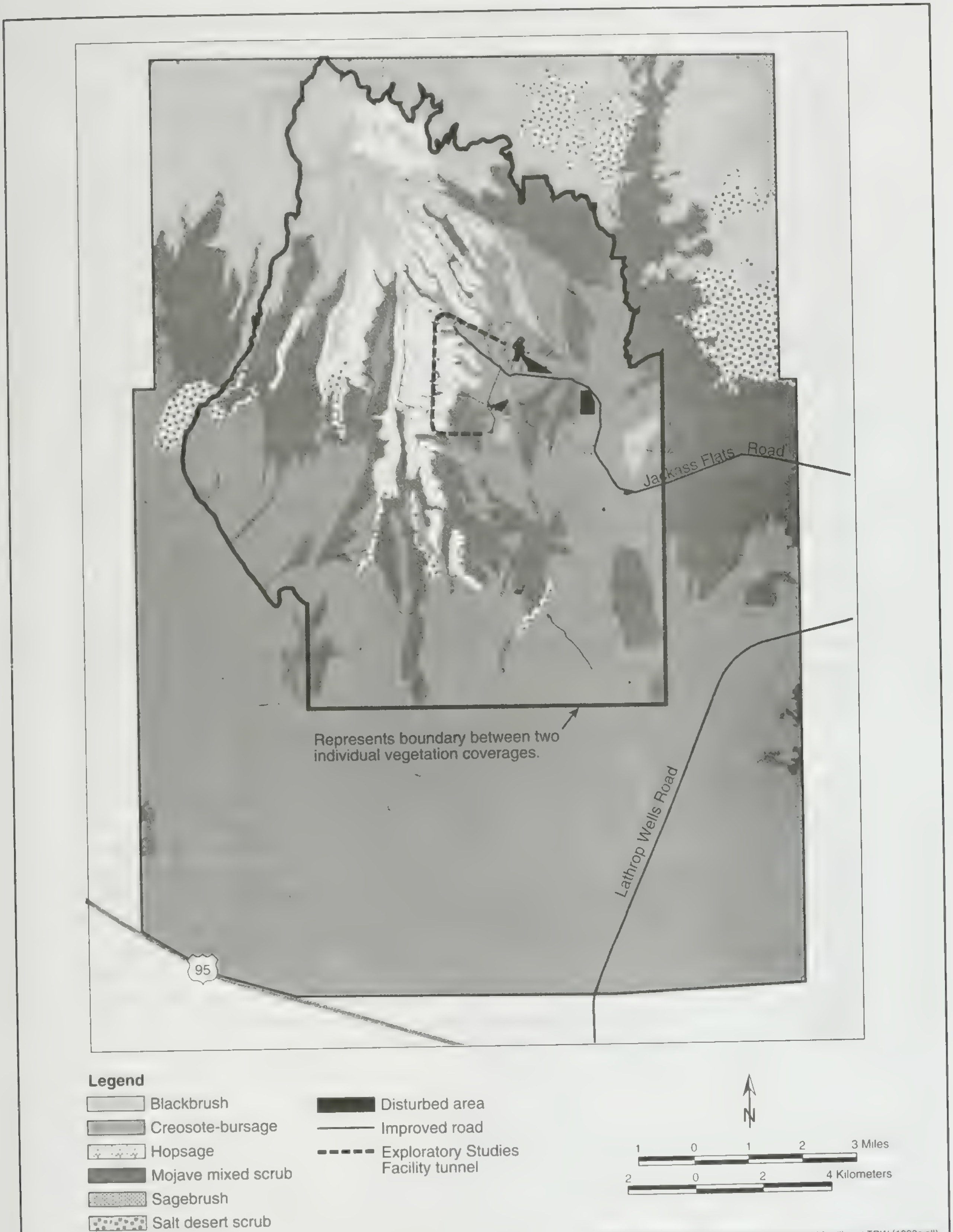
The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam's kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus*



Source: Adapted from Utah State University (1996, all) and TRW (1998c all)

Figure 3-18. Vegetation types in the analyzed land withdrawal area.

hemionus), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

3.1.5.1.3 *Special Status Species*

SPECIAL STATUS SPECIES

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

Candidate species are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. No plant species classified as sensitive by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

One animal species that occurs at Yucca Mountain, the desert tortoise, is listed as threatened under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise (Rautenstrauch, Brown, and Goodwin 1994, page 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (TRW 1999k, all).

Individual threatened bald eagles (*Haliaeetus leucocephalus*) or endangered peregrine falcons (*Falco peregrinus*) occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. The State of Nevada has classified both birds as endangered.

No other Federally listed threatened or endangered species or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur

in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows is about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows is outside the region of influence for biological resources, it contains a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have riparian vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DOE 1997f, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-19) at Yucca Mountain (Resource Concepts 1989, all); none of these series is classified as prime farmland. Based on a wetlands assessment at the Nevada Test Site (Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

SOIL TERMS

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

Piedmont: Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

Table 3-19. Soil mapping units at Yucca Mountain.[a]

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes.	Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes.	Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources.	Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

a. Source: TRW (1999l, pages 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to *excessively drained*, which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a pH ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential traditional cultural properties. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its

CULTURAL RESOURCES

Archaeological site: The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

Traditional cultural property: A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (TRW 1999m, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all).

3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash and in lower Fortymile Canyon just east of the Yucca Mountain site.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 826 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places*, but 150 are potentially eligible for nomination (see Table 3-20). Several reports describe the specific procedures used to study and protect these cultural sites (Buck and Powers 1995, all; DOE 1992a, all). DOE (1988b, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian

Table 3-20. Sites in the Yucca Mountain region potentially eligible for the *National Register of Historic Places*.

Type	Number
Temporary camps	43
Extractive localities	14
Processing localities	9
Localities	77
Caches	2
Stations	1
Historic sites	4
Total	**150**

Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between Native Americans and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-20).

Temporary Camps. When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

Extractive Localities. These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

Processing Localities. Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

Localities. This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

Caches. Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

Stations. Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

Historic Sites. Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

3.1.6.2 Native American Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (Stoffle 1987, page 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-19 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (Stoffle et al. 1990, page 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (Stoffle, Evans, and Harshbarger 1989, pages 30 to 74; Stoffle et al. 1990, pages 11 to 25; Stoffle, Olmsted, and Evans 1990, pages 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (Stoffle et al. 1989, pages 22 to 139).

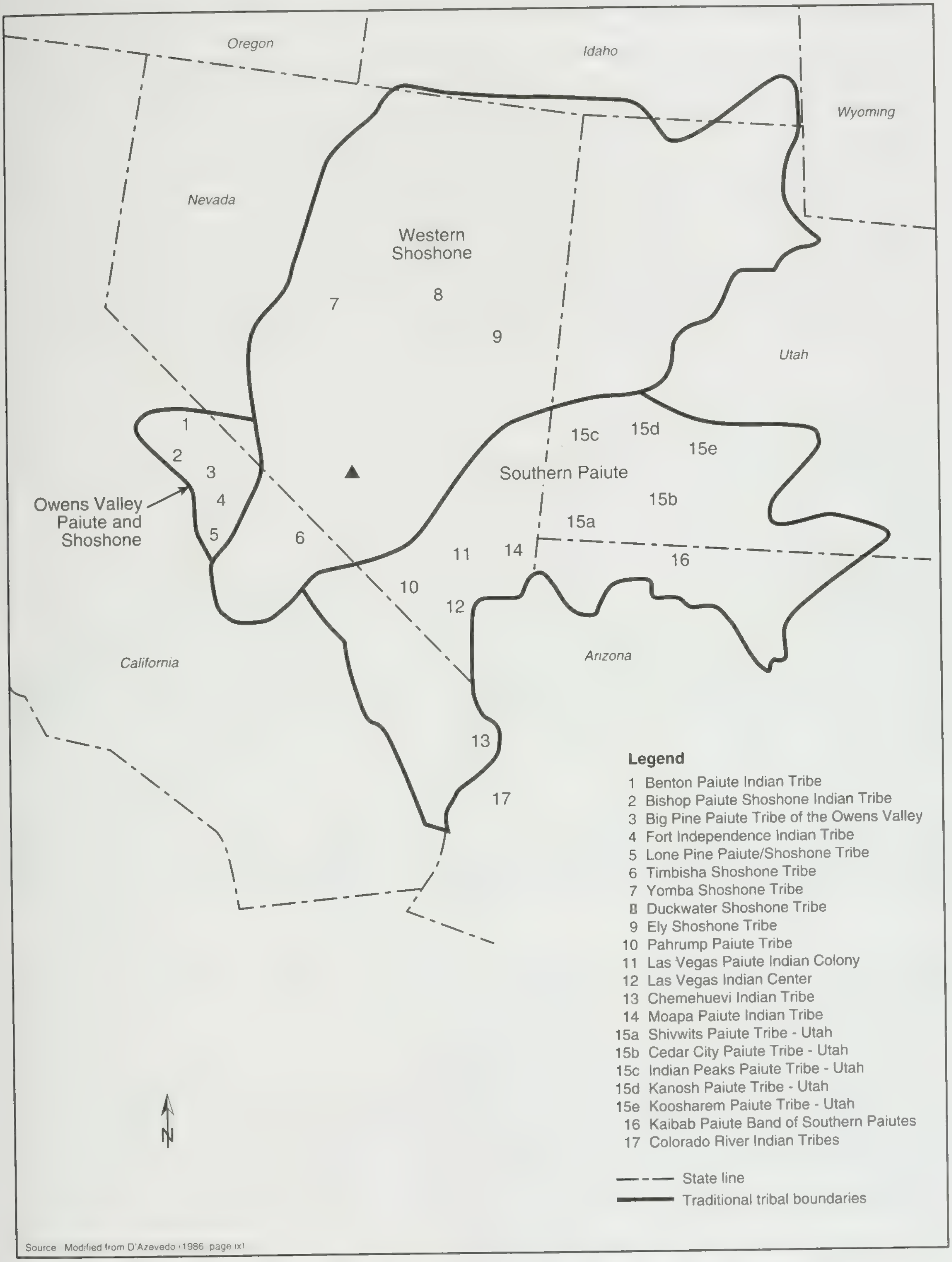


Figure 3-19. Traditional boundaries and locations of tribes in the Yucca Mountain region.

3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal groups (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native American people believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native American people used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (Stoffle et al. 1990, page 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area. Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native American people, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They

believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the counties where about 90 percent of the DOE workforce lives. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Socioeconomics* (TRW 1999n, all) is the basis for the information in this section.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. The reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and determined that the information provided was consistent with the information used in this EIS.

The socioeconomic region of influence for the Proposed Action consists of Clark, Lincoln, and Nye Counties in southern Nevada (Figure 3-20). Clark County contains the City of Las Vegas and its suburbs. Based on a count of respondents to a 1994 survey, an estimated 79 percent of Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County (Table 3-21). The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there.

Table 3-21. Distribution of Yucca Mountain Project and Nevada Test Site onsite employees (survey respondents) by place of residence.[a]

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Lincoln County	5	0.3
Nye County	310	19
Total region of influence	**1,583**	**98**
Outside region of influence	31	2
Total respondents	***1,614***	***100.0***

a. Source: TRW (1994a, all).

3.1.7.1 Population

DOE used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions at the conclusion of site characterization (Treyz, Rickman, and Shao 1992, all).

Southern Nevada has been and continues to be one of the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a average annual growth rate of 4 percent between 1980 and 1990, the United States had a growth rate of less than 1 percent during the same period (Bureau of the Census 1999, all). This trend has increased during the 1990s. From 1990 to 1997, the region of influence had an annual growth rate of 5.5 percent, averaging 51,000 new residents annually. In 1997, the population of the region increased 5.4 percent and added 57,000 new residents, bringing the estimated population to about 1.14 million. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 1997, Nevada had an annual growth rate of 4.5 percent compared to the 1-percent annual growth rate of the United States.

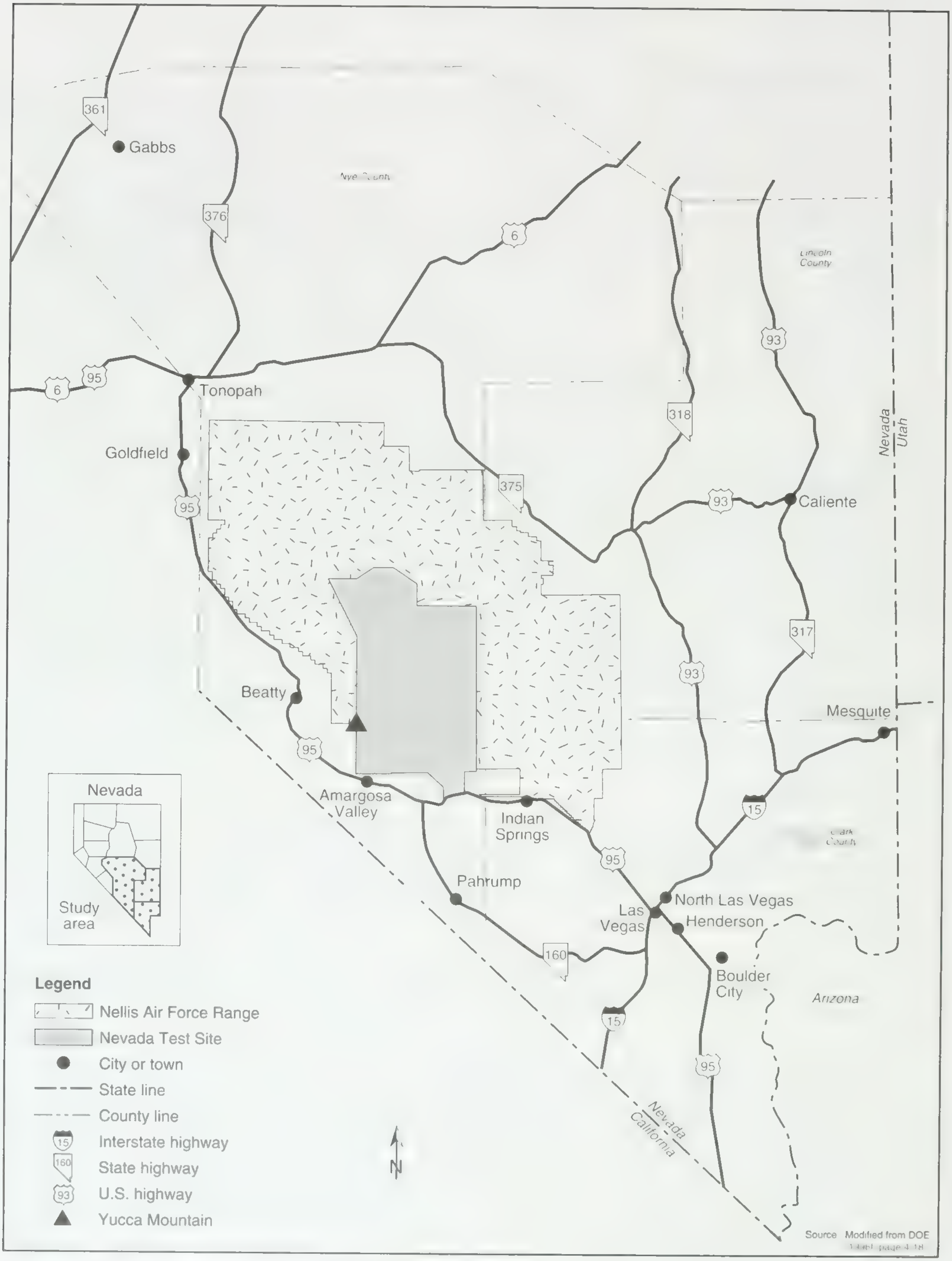


Figure 3-20. Socioeconomic region of influence.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel and gaming industry. As the popularity of gaming grew in the 1970s and 1980s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 1997, Las Vegas hosted 30.5 million visitors, contributing $25 billion to the local economy (LVCVA 1999, all). The tourism trend is expected to continue well into the next century. The relatively inexpensive land, Sunbelt climate, and favorable business conditions have also contributed to commercial and residential growth.

Another factor influencing strong growth is the number of retirees moving to communities in the region of influence. The pleasant climate, abundance of recreational opportunities, and Nevada's favorable tax structure have attracted retirees from across the United States.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 19 percent of the Yucca Mountain Project workforce (Table 3-21). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees.

In 1997, Nye County had about 26,000 residents, and it has experienced a 3.7-percent annual growth rate in the 1990s. The 1997 population in Lincoln County was about 4,200, up from about 3,800 in 1990. Although the annual growth rate of the region of influence is likely to slow, the population should increase 2 to 4 percent a year in the next decade. Clark County should lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities as well as unincorporated towns (Table 3-22). The largest city in Clark County is Las Vegas, followed by Henderson. In 1997, Las Vegas had a population of about 430,000 compared to Henderson, which had about 150,000 residents. Nye County has one incorporated city, but the largest community is unincorporated Pahrump, which had an estimated population of about 19,000 in 1997. Lincoln County also has only one incorporated city, Caliente, which is the largest community. In 1997, Caliente had a population of about 1,100.

Table 3-22. Population of incorporated cities and selected unincorporated towns, 1991 to 1997.[a,b]

Jurisdiction	1991	1995	1997
Clark County			
Boulder City	13,000	14,000	14,000
Henderson	77,000	120,000	150,000
Indian Springs[c]	N/A[d]	N/A	1,200
Las Vegas	290,000	370,000	430,000
Mesquite	2,100	5,100	9,300
North Las Vegas	51,000	78,000	93,000
Nye County			
Amargosa Valley[c]	N/A	N/A	990
Beatty[c]	N/A	N/A	1,600
Gabbs	680	360	400
Pahrump[c]	N/A	N/A	19,000
Tonopah[c]	N/A	N/A	2,800
Lincoln County			
Caliente	1,100	1,200	1,100

a. Source: TRW (1999n, all).
b. Population numbers have been rounded to two significant figures.
c. Selected unincorporated towns.
d. N/A = not available.

3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 1995, the estimated employment was about 620,000. This constituted 98 percent of the regional employment and about 64 percent of the State employment. During the same year Nye County had an employment of about 11,000, and the Lincoln County employment was about 2,100. Clark County should continue to outpace the growth of the other counties in the region.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-23). Since 1990 that pace has increased to more than 30,000 new jobs a year with an average annual growth rate of 6.1 percent. Total employment increased 35 percent between 1990 and 1995, adding about 160,000 jobs. By 2000, Clark County is expected to have an employment of about 860,000, continuing to create over 2,000 new jobs a month. The services employment sector is the largest in Clark County, representing 46 percent of the employment in 1995.

Table 3-23. Clark County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*230,000*	*410,000*	*560,000*	*780,000*
Agriculture, forestry, and fisheries	1,300	3,900	6,200	9,000
Mining	590	820	1,200	1,300
Construction	16,000	41,000	53,000	79,000
Manufacturing	7,300	12,000	18,000	20,000
Transportation and public utilities	14,000	21,000	29,000	37,000
Wholesale trade	6,500	14,000	19,000	24,000
Retail trade	44,000	72,000	98,000	130,000
Finance, insurance, and real estate	20,000	32,000	44,000	55,000
Services	120,000	210,000	290,000	420,000
Government (totals)	*38,000*	*51,000*	*62,000*	*79,000*
Federal Government - civilian	4,800	6,900	7,800	7,700
Federal Government - military	11,000	11,000	9,500	10,000
State and local government	22,000	33,000	45,000	11,000
Farm	*420*	*400*	*300*	*310*
Totals	***268,420***	***460,000***	***620,000***	***859,310***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all); 2000: estimated.

b. Employment numbers have been rounded to two significant figures.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-24). The services sector represented the largest in the Nye County economy. In 1995, services comprised 47 percent of the employment. Projections indicate that employment will decline to about 10,000 by 2000. Lincoln County employment also declined between 1990 and 1995 after growth during the 1980s (Table 3-25). In 1995, Lincoln County had a employment of about 2,100, a decline of 13 percent from 1990. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy. In 1995, services comprised 39 percent of the employment.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect jobs. About 14,000 hotel rooms were added between 1996 and 1998. Five new major resorts under construction with completion dates between Spring 1998 and Spring 2000 will add about 14,000 hotel rooms (*Las Vegas Sun* 1998, all). Despite an inventory of more than 100,000 rooms, hotels consistently operate at 90 percent occupancy, reaching to 97 percent on weekends.

Table 3-24. Nye County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*6,900*	*12,000*	*9,600*	*11,000*
Agriculture, forestry, and fisheries	50	70	110	120
Mining	1,100	2,000	1,400	1,000
Construction	410	390	560	1,000
Manufacturing	88	160	250	290
Transportation and public utilities	[210]	[280]	280	380
Wholesale trade	25	49	100	150
Retail trade	530	960	1,200	1,800
Finance, insurance, and real estate	[360]	[290]	450	490
Services	4,100	7,700	5,200	5,500
Government (totals)	*770*	*1,200*	*1,500*	1,700
Federal Government - civilian	130	200	200	*200*
Federal Government - military	100	77	53	79
State and local government	540	930	1,200	1,400
Farm	*220*	*260*	*210*	210
Totals	***7,890***	***13,360***	***11,310***	***12,910***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.
b. Employment numbers have been rounded to two significant figures.

Table 3-25. Lincoln County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*1,300*	*1,712*	*1,380*	*1,558*
Agriculture, forestry, and fisheries	[4]	[30]	22	24
Mining	310	30	18	14
Construction	75	47	44	24
Manufacturing	12	[10]	10	37
Transportation and public utilities	96	88	62	62
Wholesale trade	12	10	[17]	41
Retail trade	310	250	[270]	386
Finance, insurance, and real estate	51	47	68	74
Services	380	[1,200]	[869]	846
Government (totals)	*400*	*537*	*607*	*573*
Federal Government - civilian	25	45	39	34
Federal Government - military	12	12	*8*	9
State and local government	360	480	560	530
Farm	*160*	*180*	*150*	*149*
Totals	***1,860***	***2,429***	***2,137***	***2,280***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.
b. Individual employment numbers have been rounded to two significant figures.

Because of the thousands of new jobs added to the economy each month, the Las Vegas area has a low unemployment rate. In 1997, Clark and Nye Counties had unemployment rates below the Nevada and national rates at 4.0 percent and 3.9 percent, respectively. The planned closing of the Bullfrog Mine in Nye County will increase unemployment. In 1997, the Bullfrog Mine employed approximately 290 workers; however, it will probably close in 2000 (Meyers 1998, all). Lincoln County had an unemployment rate above the national average at 7.8 percent (Reel 1998, all). The State of Nevada had an unemployment rate of 4.1 percent and the United States had a rate of 4.9 percent (NDETR 1999, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 1997, and are not likely to fluctuate substantially through the end of site characterization activities.

In 1997, an average of about 1,600 workers (140 on the site and 1,460 off the site) worked on the Yucca Mountain Project. Most offsite workers are in the Las Vegas area (TRW 1998d, all). The employment projection for 2000 reflects expected changes due to new hotel construction, closure of the Bullfrog Mine, and Yucca Mountain Project employment.

3.1.7.3 Payments Equal to Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act of 1982, as amended, requires the Secretary of Energy to "...grant to the State of Nevada and any affected unit of local government an amount each fiscal year equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities...." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (NLCB 1996, all).

The estimated sales and use taxes, property taxes, and Nevada business taxes Yucca Mountain Project organizations paid from May 1986 through June 1996 have been totaled. These organizations paid sales or use taxes of $2.25 million for purchases consumed in Clark County and $3.8 million in Nye County, paid property or possessory taxes of about $110,000 in Clark County and $37,355 in Nye County, and paid Nevada business taxes of about $460,000 (NLCB 1996, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 1996 was about $1.68 million for purchases consumed in Clark County and $240,000 in Nye County. For property taxes it was about $200,000 in Clark County, $14.8 million in Nye County, $8,000 in Lincoln County, $3,700 in Esmeralda County, and $24,000 in Inyo County. For Nevada business taxes, about $95,000 has been paid.

3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1996, a record 19,000 units were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competition has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $190,000. The average home sold for about $131,000 in 1996. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 150,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Clark County in 2000 is about 570,000.

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Nye County in 2000 is about 12,000.

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Lincoln County in 2000 is about 1,800.

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

3.1.7.5 Public Services

Education. In the 1996-1997 school year, the region of influence contained about 180 elementary and middle schools, 34 high schools, 13 alternative schools, and 4 special education schools. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (Clark County 1997a, all; NDE 1997, page 4). In 1997, the national pupil-teacher ratio was about 19-to-1 for elementary schools and 15-to-1 for secondary schools (USDE 1999, all). Clark County has the tenth-largest school district in the country; during the 1996-1997 school year, Clark County had about 210 schools and nearly 180,000 students (Table 3-26). During the same period, Nye County had 16 schools and fewer than 5,000 students, and Lincoln County had nine schools and about 1,000 students (Clark County 1997a, all; TRW 1999n, all; NDE 1997, page 4).

Because Clark County is experiencing rapid growth, voters have passed three bond issues totaling $1.85 billion dollars since 1988 to renovate existing schools and build new schools. The most recent was a $643 million bond in 1996. Eleven new schools—six elementary, three middle, and two high schools—were scheduled to open during the 1997-1998 school year (Clark County 1998, all). Nye County was scheduled to seek approval in a 1998 bond issue to build a new middle and elementary school over the next few years (Harge 1997, page 18).

Table 3-26. Enrollment by school district and grade level.[a,b]

District	Actual 1996-1997[c]	Projected 2000-2001[d]
Clark County[e]		
Prekindergarten	1,000	1,300
Kindergarten	15,000	19,000
Elementary (grades 1-6)	90,000	110,000
Secondary (grades 7-12)	73,000	91,000
District totals	**179,000**	**221,300**
Nye County[f]		
Prekindergarten	43	44
Kindergarten	310	380
Elementary (grades 1-6)	2,300	2,400
Secondary (grades 7-12)	2,200	2,300
District totals	**4,853**	**5,124**
Lincoln County[g]		
Prekindergarten	22	20
Kindergarten	57	51
Elementary (grades 1-6)	400	360
Secondary (grades 7-12)	630	570
District totals	**1,109**	**1,001**

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their condition; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures.
c. Enrollments for the 1996-1997 school year are as of the end of the first school month.
d. Projected enrollment for the 2000-2001 school year is based on the ratio of actual 1996-1997 figures to the 1996 population estimate multiplied by the 2000 population forecast.
e. Source: Clark County (1997a, all).
f. Source: NDE (1997, page 4).
g. Source: TRW (1999n, all).

Health Care. Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 1995, Clark County had seven hospitals and four specialized care facilities. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (Rodefer et al. 1996, all). Table 3-27 lists hospital use in the region of influence.

Table 3-27. Hospital use by county in the region of influence.[a,b]

County	1990	1995	2000
Clark			
Population	750,000	1,000,000	1,310,000
Average number of beds	2,000	2,100	2,900[c]
Beds per 1,000 residents	2.6	2.2	2.2[d]
Patient-days	490,000	530,000	700,000[e]
Nye			
Population	18,000	24,000	26,000
Average number of beds	21	21	22[c]
Beds per 1,000 residents	1.2	0.86	0.86[d]
Patient-days	1,800	1,900	2,000[e]
Lincoln			
Population	3,800	3,900	3,400
Average number of beds	5	4	4[c]
Beds per 1,000 residents	1.3	1.0	1.0[d]
Patient-days	520	360	310[e]

a. Source: Rodefer et al. (1996, pages 214 to 216).
b. All numbers have been rounded to two or three significant figures.
c. Calculated assuming number of beds per 1,000 residents remained constant.
d. Held constant at 1995 levels.
e. 2000 patient-days calculated by multiplying 2000 population by 1995 ratio of patient-days to population.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

Law Enforcement. The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 1996, it had about 1,200 employees, a ratio of about 1.2 employees per 1,000 residents. In 1996, the Nye County Sheriff Department had 110 employees, a ratio of 4.4 employees per 1,000 residents, and Lincoln County had 14 sheriff department employees, a ratio of 3.7 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (FBI 1996, pages 1 to 3). Assuming that the number of employees per 1,000 residents remains the same, the expected law enforcement staffing in 2000 will be about 1,600 in Clark County, 120 in Nye County, and 15 in Lincoln County.

Fire Protection and Emergency Management. A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 1992, Clark County had about 1,100 paid, 420 volunteer, and 80 seasonal or inmate firefighters, a ratio of 1.9 firefighters per 1,000 residents. In 1992, Nye County had 150 paid and 330 volunteer firefighters, a ratio of about 25 firefighters per 1,000 residents, and Lincoln County had 73 volunteer firefighters, a ratio of about 19 firefighters per 1,000 residents. The national average is 4.1 firefighters (full and volunteer) per 1,000 residents.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 28,000. The region of influence encompasses communities in Nye and Clark Counties in Nevada, as well as Inyo County in California (Figure 3-21). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (TRW 1999o, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment. Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region. Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

3.1.8.1 Radiation Sources in the Environment

There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of ionizing radiation: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources include cosmic radiation from space, *terrestrial* radiation from natural radioactive sources in the ground (radon, for example), radiation from radionuclides naturally present in the body, and inhaled and ingested radionuclides of natural origin. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, air travel, especially at very high altitudes, increases exposure to cosmic radiation, and tunneling through rock (as at Yucca Mountain) increases worker exposure to naturally occurring sources. A variety of exposures result from manmade materials and devices such as radiopharmaceuticals and X-rays in medicine, and consumer products such as some smoke detectors. Exposures can also result from episodic events, such as uncontained nuclear weapons tests.

External background radiation comes from two sources of approximately equal magnitude: cosmic radiation from space and terrestrial gamma radiation from radionuclides in the environment, mainly from the Earth itself. In the case of cosmic radiation, charged particles (primarily protons from extraterrestrial sources) have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main contributors to the terrestrial gamma radiation field are potassium-40 and the members of the thorium and uranium decay series. Most terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products.

Cosmogenic radionuclides are produced by interactions of cosmic particles with certain atoms in the atmosphere or in the Earth. There are four cosmogenic radionuclides of interest for internal doses: tritium (hydrogen-3), beryllium-7, carbon-14, and sodium-22. With the exception of beryllium-7, all are isotopes of important elements in the human body. The dose rates from natural cosmic, cosmogenic, and terrestrial radiation vary throughout the world depending on such factors as altitude and geology. Natural background radiation is the largest contributor to the average radiation dose to individuals and is the most variable component of background radiation. Table 3-28 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations.

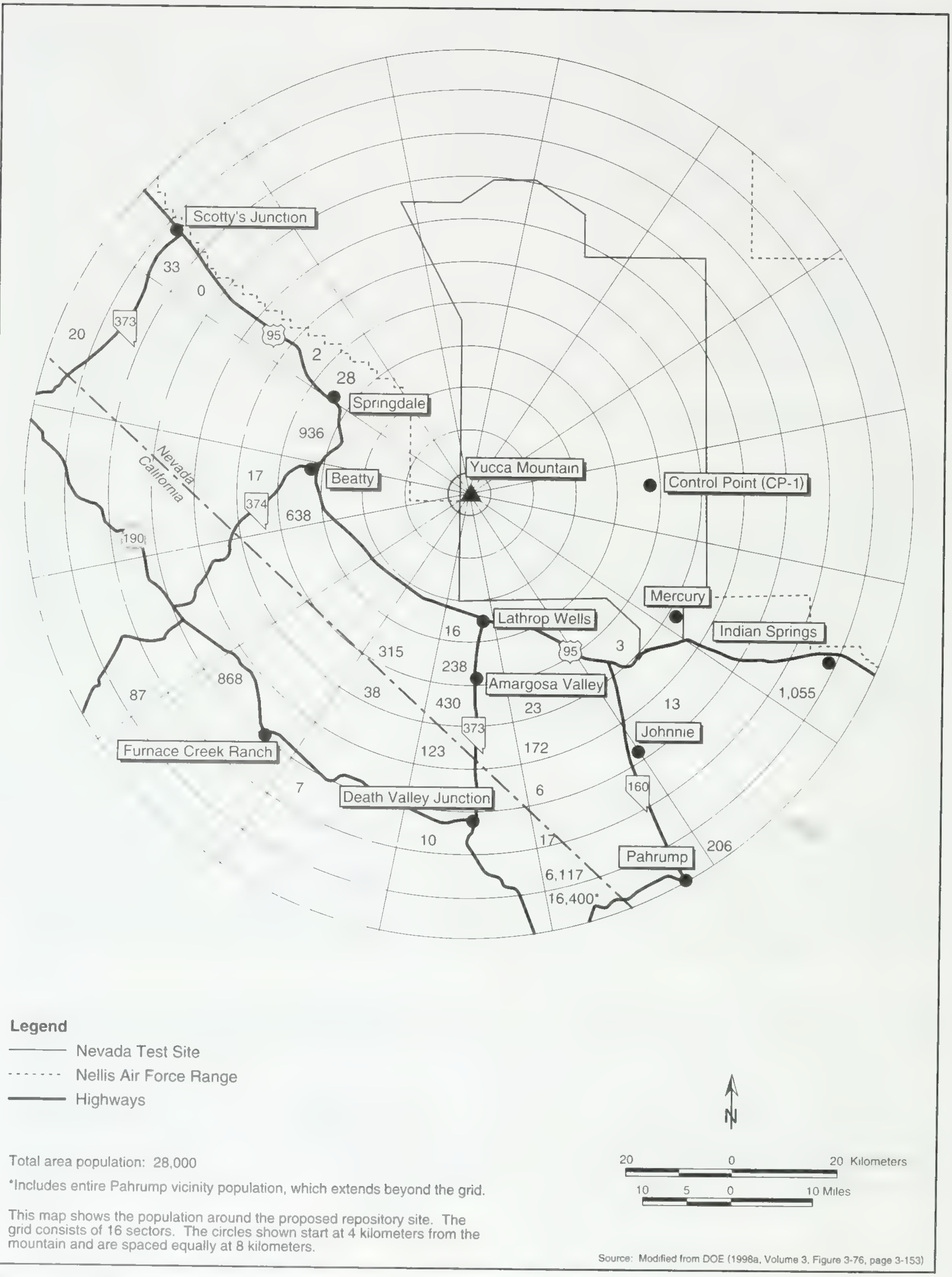


Figure 3-21. Population distribution within 80 kilometers (50 miles) of the proposed repository site, year 2000 estimate.

Table 3-28. Radiation exposure from natural sources (millirem per year).[a]

	Annual dose (effective dose equivalent)					
					Region of influence	
Source	U.S. average	Aiken[b]	Oak Ridge[c]	Las Vegas	Amargosa Valley	Beatty
Cosmic and cosmogenic	28	33	29	(d)	40	(d)
Terrestrial	28	43	38	89	56	150
Radon in homes (inhaled)[e]	200	200	200	200	200	200
In body	40	40	40	40	40	40
Totals[f]	**300**	**320**	**310**	**330**	**340**	**390**

a. Sources: Bechtel (1998, page 4-31); DOE (1995e, pages 4-211 and 4-394); NCRP (1987, Section 2).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge National Laboratory.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is measured in rem. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

Picocurie per liter: A unit of measure describing the amount of radioactivity in a liter of a given substance (for example, air or water). A picocurie is one one-trillionth of a curie.

Roentgen: A unit of measure of X-ray or gamma-ray radiation exposure described in terms of the amount of energy transferred to a unit mass of air. One roentgen corresponds to the absorption of 87.7 ergs (about 6.5×10^{-6} foot-pound) per gram of air.

Rem: The dose of an ionizing radiation that will cause the same biological effect as 1 roentgen of X-ray or gamma ray exposure (rem means Roentgen Equivalent in Man).

Radiation can cause a variety of adverse health effects in people. A large dose of radiation can cause prompt death. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer*

fatalities because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in person-rem. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (NCRP 1993a, page 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have been endorsed by the International Commission on Radiological Protection, Environmental Protection Agency, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The factors apply if the dose to an individual is less than 20 rem and the dose rate is less than 10 rem per hour. At doses greater than 20 rem, the factors used to relate radiation doses to latent cancer fatalities are doubled. At much higher doses, prompt effects, rather than latent cancer fatalities, might be the primary concern.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities per year).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 divided by 4 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

The same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

$$\begin{aligned}\text{Latent cancer fatality} &= 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \\ &\quad \times 0.0005 \text{ latent cancer fatality per person-rem} \\ &= 0.011 \text{ latent cancer fatality.}\end{aligned}$$

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. The baseline Nevada cancer fatality rate in a population of 100,000 is about 185 deaths per year (ACS 1998, page 6), resulting in a baseline rate of about 50 cancer deaths per year in the region of influence.

3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-28). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (Bechtel 1998, page 7-5). Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 16 kilometers (10 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.09 millirem. The estimated maximum annual radiation dose for a hypothetical individual at the Nevada Test Site boundary is 0.12 millirem. These doses, which are about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), are conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive noble gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.22 to 72 picocuries per liter, with a median concentration of about 6.5 picocuries per liter (TRW 1999o, page 12). The median annual dose to involved workers from inhalation of radon and decay products underground was estimated to be about 60 millirem. Appendix F contains additional information on the estimated underground external dose to involved workers from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface in the Amargosa Valley region (see Table 3-28).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is about 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about

0.6 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-28. Appendix G contains additional information on the estimated releases of radon from the repository.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DOE 1998a, Volume 1, pages 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (EPA 1996a, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (TRW 1999b, page 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (ACGIH 1999, page 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a carcinogen (IARC 1997, page 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Experimental Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low doses erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the

other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total recordable incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Table F.2-3). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-29 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

Table 3-29. Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

Statistic	Total industry[b]	General construction[b]	General mining[b]	Yucca Mountain experience from DOE CAIRS data base, involved workers[c]
Total recordable cases rate	7.1	9.5	5.9	6.8
Lost workday cases rate	3.3	4.4	3.7	4.8
Lost workdays rate	Not available	Not available	Not available	100

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: BLS (1998, all).
c. Source: Appendix F, Table F.2-3.

3.1.9 NOISE

Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (Brattstrom and Bondello 1983, page 170).

NOISE MEASUREMENT

What are *sound* and *noise*?

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

How is sound measured?

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DOE (1999g, page 3-39).

TYPICAL A-WEIGHTED SOUND LEVELS

	DECIBELS	
50-horsepower siren (33 meters)[a]	140	
Jet takeoff (66 meters)	130	
Riveting machine[b]	120	Diesel motors
Cut-off saw Pneumatic peen hammer[b]	110	
Rock drill (16 meters) Textile weaving plant[b]	100	Outdoor public address system loudspeakers
Subway train (6.6 meters) Dump truck (16 meters) Pneumatic drill (16 meters)	90	Ventilation fans
Freight train (33 meters) Vacuum cleaner (3.3 meters)	80	Inside sports car (24 meters per second)[c]
Speech (0.33 meters) Passenger auto (16 meters)	70	
Large transformer (66 meters)	60	Near freeway (auto traffic) Large store Accounting office
	50	Private business office Light traffic (33 meters) Average residence
Soft whisper (13 centimeters)	40	
	30	Studio (speech)
	20	Quiet
Threshold of hearing (youths)	10	
	0	

a. To convert meters to feet multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (Brown-Buntin 1997, pages 4-6). Table 3-30 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound

Table 3-30. Estimated sound levels in southern Nevada environments.[a]

Environment	Sound level[b] (decibels)
Calm day at Yucca Mountain	22
Windy day at Yucca Mountain	38
Rural communities (Panaca, Hadley, Rachel, Alamo, Jean, Goodsprings, Sandy)	40 - 47
Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Lathrop Wells, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain	45 - 55
Suburban parts of Las Vegas	52 - 60
Urban parts of Las Vegas	56 - 66
Dense urban parts of Las Vegas with heavy traffic	64 - 74
Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway)	78 - 88

a. Source: modified from EPA (1974, page 14); Brattstrom and Bondello (1983, page 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (EPA 1974, page 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

3.1.10 AESTHETICS

Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

The Bureau of Land Management uses four visual resource classes in the management of public lands (BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (BLM 1986, all). There are three scenic quality classes in the Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, public interest in the area, and adjacent land uses.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Lathrop Wells on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (TRW 1999p, all).

BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES (used in the management of public lands)

Class I	The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.
Class II	The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
Class III	The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
Class IV	The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (TRW 1999j, all) is the basis of the information in this section.

3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

Water. The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes

from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; SNWA 1997, page 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (Buqo 1996, all). In Beatty (Oasis Valley Hydrographic Area), the local water utility will have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. Existing pumping capacity is not adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells will be needed. In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin's perennial yield, which range from 15 million cubic meters [12,000 acre-feet (NDWP 1992, page 7)] to 23 million cubic meters [19,000 acre-feet (Buqo 1996, page 17)]. Much of Pahrump's water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about two wells a year (Buqo 1999, page 34). Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (Horton 1997, Table 1).

Sewer. Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (Clark County 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County, and communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

3.1.11.2 Energy

Electric Power. Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 1996, the power sources were 50 percent company-generated (38 percent coal, 12 percent natural gas), 4 percent Hoover Dam hydroelectric, and 46 percent purchased power. In 1996, Nevada Power Company sold 13.7 million megawatt-hours to its 490,000 customers, with average annual sales per residential customer of about 13,000 kilowatt-hours. In 1996, the peak load was the highest ever at about 3,300 megawatts with a generating capacity and firm purchases of about 3,900 megawatts. Nevada Power Company has an annual customer growth rate of 7.2 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 1996, it invested about $180 million in such equipment (NPC 1997, all).

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (McCauley 1997, pages 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-22). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the historic monthly peak use was about 18,000 megawatt-hours in January 1992, with a peak load of about 37 megawatts (Thurman 1997, page 1).

Table 3-31 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (Thurman 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until

Table 3-31. Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

	Power use	
Fiscal Year	Consumption (megawatt-hours)	Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[c]	21,000	4.2
1999[c]	17,000	4.2
2000[c]	8,700	4.2

a. Source: TRW (1998a, Table 2, page 8).
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Projected.

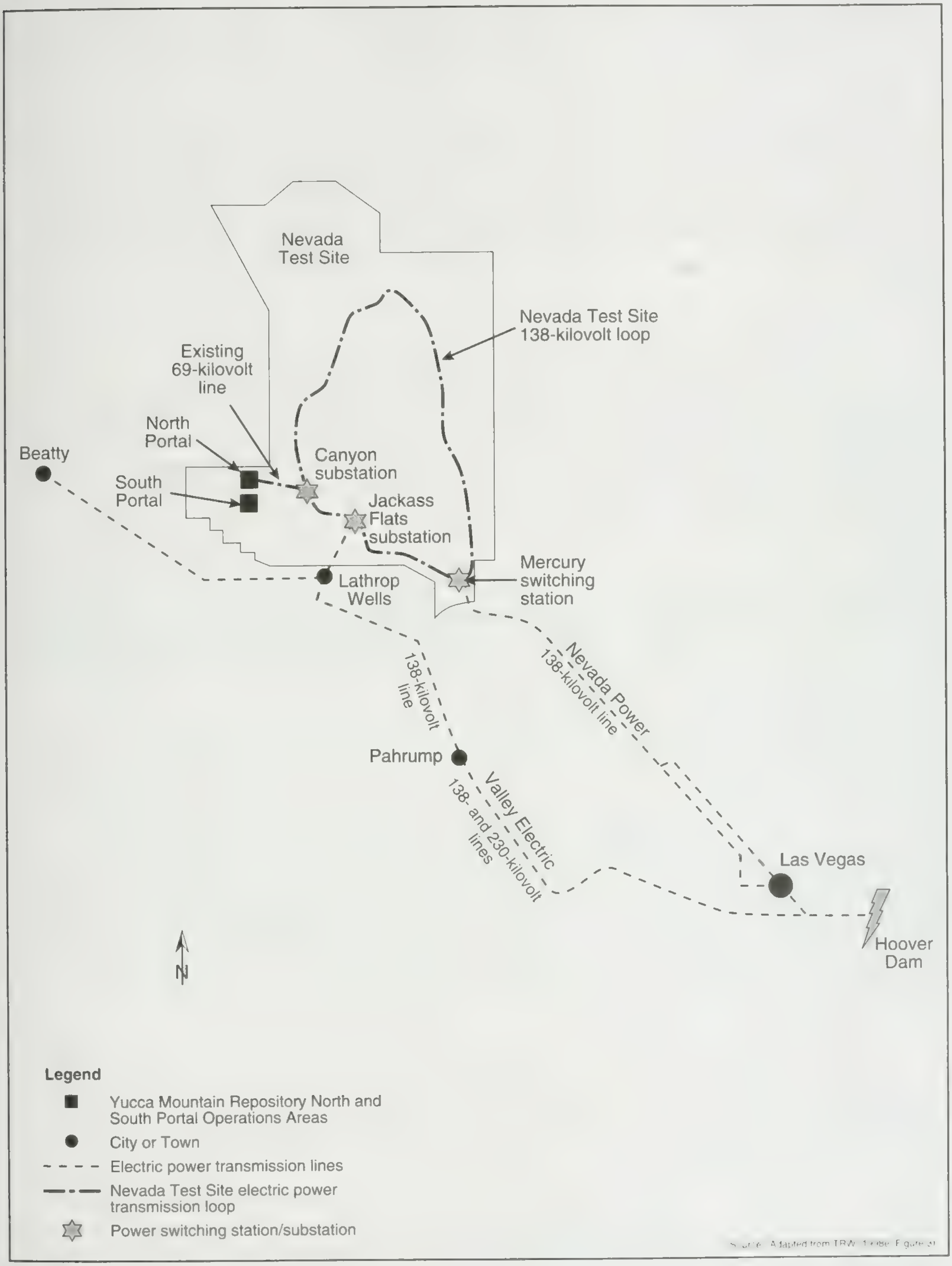


Figure 3-22. Existing Nevada Test Site electric power supply.

repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (TRW 1998a, Table 2, page 8).

Fossil Fuel. The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DOE 1998k, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (Harris 1997, Page 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of sanitary waste. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37) and a 100-year estimated life (DOE 1995f, page 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37) and an estimated 70-year operational life (DOE 1995f, page 8). The environmental impact statement for the Nevada Test Site describes these landfills (DOE 1996f, page 4-37). DOE disposes of Yucca Mountain Site

Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (Harris 1997, page 4).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DOE 1997h, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (Harris 1997, pages 1 to 3).

3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site (Harris 1997, page 5), and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility under contract to the Nevada Test Site (Harris 1997, page 5).

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (TRW 1998f, page 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (TRW 1998g, page 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (Harris 1997, page 2). The oil is recycled with the other used oil generated by the project.

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.1 million cubic meters (110 million cubic feet). DOE estimates that a total of approximately 670,000 cubic meters (23.7 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DOE 1998l, page 2-23), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for a broad range of low-level radioactive wastes is available at two licensed facilities, and three more disposal facilities are under license review (NRC 1997a, U.S. Low-Level Radioactive Waste Disposal Section).

3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DOE 1996h, all). By using these programs, the Department is able to minimize

the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (Dixon 1999, pages 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (Dixon 1999, page 1).

3.1.13 ENVIRONMENTAL JUSTICE

ENVIRONMENTAL JUSTICE TERMS

Minority: Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

Low income: Below the poverty level as defined by the Bureau of the Census.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." In a memorandum that accompanies the Executive Order, President Clinton directs that "...environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities, [be analyzed] when such analysis is required by the National Environmental Policy Act."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for information in this section.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups*. DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (Bureau of the Census 1992a, Tables P8 and P12). As defined by the Nuclear Regulatory Commission (NRC 1995, all), a minority population is present in a community when the percentage of minority persons in the area exceeds the percentage of minority persons in the state or region affected by a project by 10 percent or more (that is, 31 percent or more minority persons in a community). This analysis identifies communities at the Bureau of the Census block group level. The following discussion uses data from the 1990 census. Figure 3-23 shows block groups in which 31 percent or more of the population consists of minority persons.

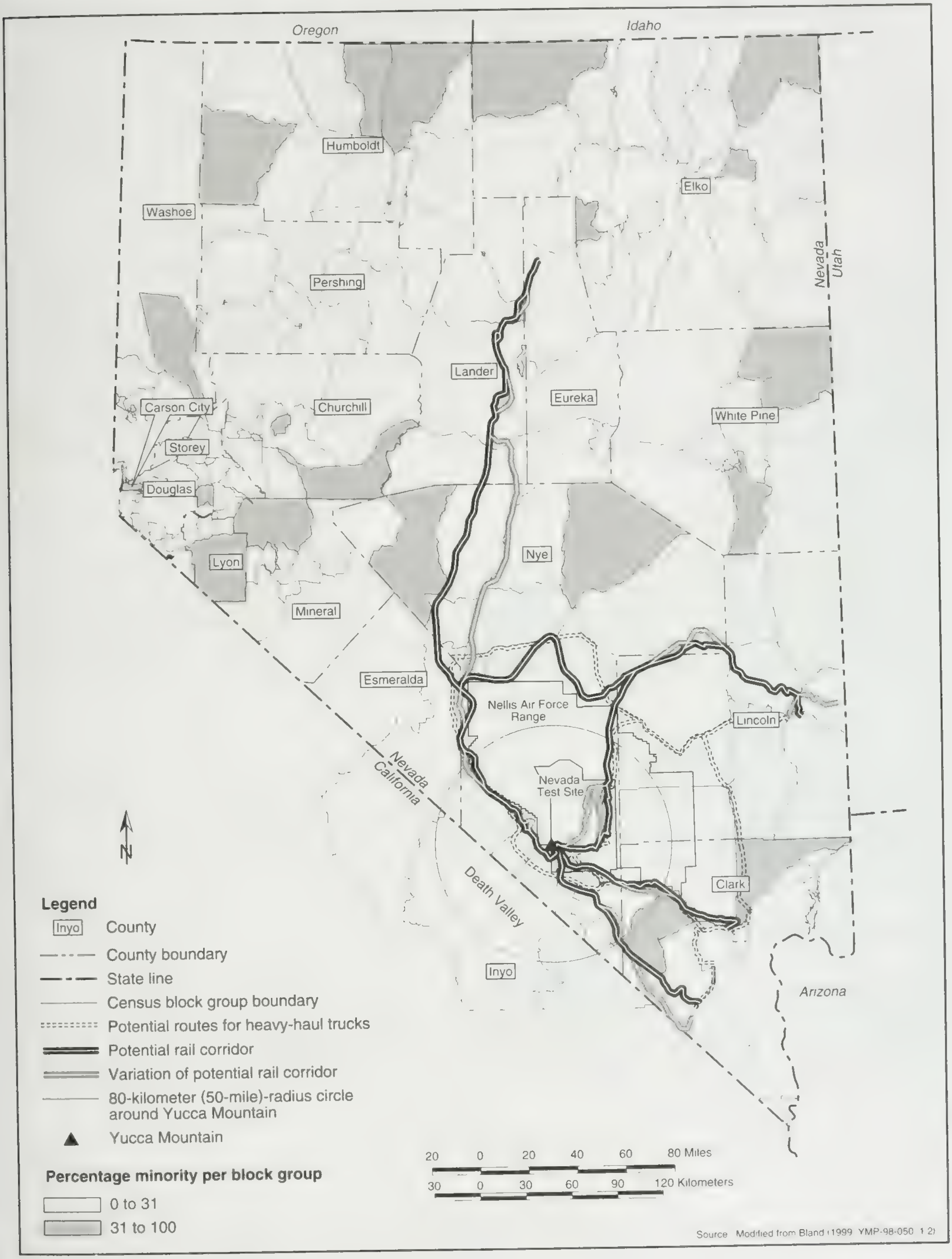


Figure 3-23. Minority communities in Nevada.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (Bureau of the Census 1992a, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-24 shows low-income communities.

3.1.13.2 Clark County

In 1990, the minority population of Clark County was about 180,000 persons, or 25 percent of the total population (Bureau of the Census 1992b, Tables P8 and P12). A total of 6,800 residents, or 11 percent of the Clark County population, was characterized as living in poverty (Bureau of the Census 1992b, Table P117) Forty-three of Clark County's 325 block groups had both minority populations greater than the 31-percent threshold necessary for identification as minority communities and populations that exceeded the 20-percent low-income community threshold. Thirty-five more block groups had minority populations greater than the 31-percent threshold. An additional 12 block groups had low-income populations greater than the 20-percent threshold. In all, the process identified 90 block groups in Clark County for environmental justice study.

3.1.13.3 Lincoln County

In 1990, the Lincoln County minority population consisted of about 370 persons, or 10 percent of the population (Bureau of the Census 1992c, Tables P8 and P12). Five hundred persons, or 14 percent of the population, were characterized as living in poverty (Bureau of the Census 1992c, Table P117). No block groups exceeded the 31-percent threshold for identification as a minority community. One of the block groups in Lincoln County exceeded the threshold for identification as a low-income community.

3.1.13.4 Nye County

In 1990, the Nye County minority population was about 2,200 persons, or 12 percent of the population (Bureau of the Census 1992d, Tables P8 and P12). There were 2,000 persons, or 11 percent of the population, characterized as living in poverty (Bureau of the Census 1992d, Table P117). Two block groups had populations that exceeded the thresholds for both minority and low-income populations. Three more of the 25 block groups in Nye County exceeded the threshold for identification as low-income communities.

3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-21). DOE performed additional review and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

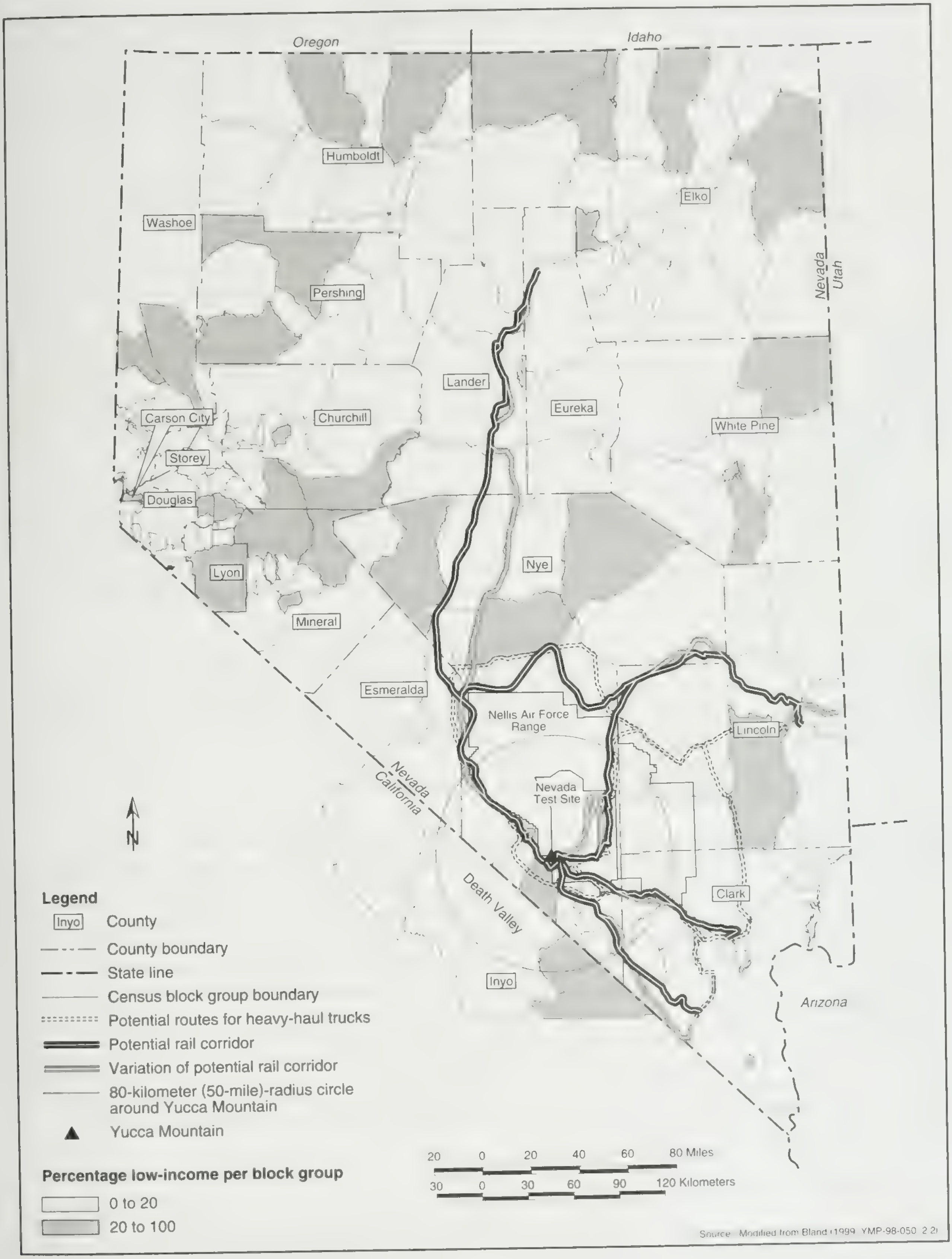


Figure 3-24. Low-income communities in Nevada.

3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the potential transportation corridors to the Yucca Mountain site. Section 3.2.1 discusses the existing national transportation infrastructure that DOE would use to ship spent nuclear fuel and high-level radioactive waste to Nevada.

Section 3.2.2 describes the existing environmental conditions along the proposed transportation corridors and routes in Nevada.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. The Department's efforts to transport these materials to the Yucca Mountain site could use trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [0.006 percent of truck miles per year or 0.007 percent of railcar miles per year (BTS 1998, page 5)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

3.2.1.1 Highway Transportation

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (Johnson et al. 1993a, all) to derive highway routes for shipping spent nuclear fuel and high-level radioactive waste. This model considered population densities along the routes, and selected existing highway routes between the commercial and DOE sites and the proposed repository in accordance with U.S. Department of Transportation routing constraints. Population density distributions were calculated along the routes to support human health risk consequences.

Appendix J describes the routes used for analysis in this EIS. Final transportation mode and routing decisions will be made on a site-specific basis during the transportation planning process, following a decision to build a repository at Yucca Mountain.

3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At

railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-29 in Chapter 2 is a map of mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (Johnson et al. 1993b, all). The selection of these routes was based on current routing activities using existing routes. Appendix J describes the rail routes used in this EIS analysis.

3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (NDOT 1997, page 9; Cerocke 1998, page 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station.

3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail

corridors Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-10 through 6-15 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

The INTERLINE computer program (Johnson et al. 1993b, all) provided population distributions for differing population zones (urban, rural, suburban) along the alternative rail corridors. This approach is consistent with the national transportation analysis (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-32 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

3.2.2.1.1 *Land Use and Ownership*

Table 3-33 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (BLM 1979, all; BLM 1994b, all; BLM 1999a, all).

Caliente. Most of the lands associated with the Caliente corridor (88 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed

Table 3-32. Regions of influence for rail implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line
Air quality and climate	The Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations
Hydrology	*Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line
Cultural resources	Lands inside the 400-meter-wide rail corridors
Socioeconomic environments	Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse
Public health and safety	800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios
Noise	Inhabited commercial and residential areas where noise from rail line construction and operations could be a concern
Aesthetics	The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations
Utilities, energy, and materials	Local, regional, and national supply infrastructure that would be required to support rail line construction and operations
Environmental justice	Varies with the individual resource area

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

Table 3-33. Land ownership for the candidate rail corridors.[a]

Corridor	Land in corridor: Totals (km^2)[b,c]	Ownership or control (percent)[d]: BLM	USAF	DOE	Private	Other
Caliente	200	88	9	2	< 1	0
Carlin	210	85	9	2	3	0
Caliente-Chalk Mountain	140	57	16	27	< 1	0
Jean	72	83	0	12	5	0
Valley Modified	64	50	14	33	0	3

a. Source: (TRW 1999d, all).
b. To convert square kilometers (km^2) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; and the single Other designation is the Desert National Wildlife Refuge managed by the Fish and Wildlife Service.

information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), the *Department of the Interior Final Environmental Impact Statement Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (BLM 1979, all), the *Draft Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (BLM 1999a, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Caliente corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Department of the Air Force Legislative Environmental Impact Statement* (USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all).

Less than 1 percent of the land associated with the Caliente corridor is private. The corridor crosses private land near Caliente.

Carlin. Most of the lands associated with the Carlin corridor (about 85 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Management Plan and Environmental Impact Statement for the Shoshone-Eureka Resource Area, Nevada* (BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor crosses into the western portion of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 3 percent of the land associated with the Carlin corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

Caliente-Chalk Mountain. Most of the lands associated with the Caliente-Chalk Mountain corridor (about 57 percent) are public lands managed by the Ely office of the Bureau of Land Management. Detailed information on land use is available in BLM (1979, all) and BLM (1999a, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain corridor is private. The combined Caliente and Caliente-Chalk Mountain corridor crosses private lands near Caliente.

Jean. Most of the lands associated with the Jean corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean corridor. The corridor enters the Nevada Test Site near the Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 5 percent of the land associated with the Jean corridor is private. The corridor crosses private lands in the Pahrump Valley.

Valley Modified. Half of the lands associated with the Valley Modified corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

The U.S. Air Force uses about 14 percent of the lands associated with the Valley Modified corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 33 percent of the lands associated with the Valley Modified corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Refuge and Nellis Air Force Range are restricted by a memorandum of understanding (USAF 1999, Appendix C).

3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

Air Quality. The Caliente, Carlin, Caliente-Chalk Mountain, and Jean corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (EPA 1999c, all). There are no State air-quality monitoring stations in these corridors (NDCNR 1999, pages A1-1 through A1-9).

The Valley-Modified rail corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers (PM_{10}). Clark County

adopted a plan for demonstrating PM_{10} attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. The Las Vegas Valley is also a nonattainment area for carbon monoxide.

Climate. There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer.

The Jean and Valley Modified corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52).

3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

3.2.2.1.3.1 Surface Water. Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (TRW 1999k, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-34 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

3.2.2.1.3.2 Groundwater. Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-35 lists results of this effort. The table also lists estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.)] (NDWP 1999b, Region 14). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. The table indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain corridors split.

Table 3-34. Surface-water-related resources along candidate rail corridors.[a]

Rail corridor	Distance from corridor (kilometers)[b]	Feature
Caliente		
Caliente to Meadow Valley	0.5	Springs – two unnamed springs, in Meadow Valley north of Caliente
	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 25 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.
	0.8	Spring – McCutchen Spring, north of Worthington Mountains
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley
	Within	Riparian area – designated area east of Oasis Valley, flowing into Amargosa Valley
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty
	Within - 0.3	Riparian area/stream – Amargosa River, with persistent water and extensive wet meadows near springs and seeps
Carlin		
Beowawe to Austin	0.5	Spring – Tub Spring, northeast of Red Mountain
	0.8	Spring – Red Mountain Spring, east of Red Mountain
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present
	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smokey Valley
	0.6	Riparian area – marsh area formed from group of 35 springs
	0.6	Spring – Mustang Spring, south of Seyler Reservoir
	0.3	Riparian/reservoir – Seyler Reservoir, west of Manhattan
Mud Lake to Yucca Mountain		See Caliente corridor
Caliente-Chalk Mountain		
Caliente to Meadow Valley		See Caliente corridor
Meadow Valley to Sand Spring Valley		See Caliente corridor
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye
	0.8	Spring – Cane Spring, on north side of Skull Mountain on Nevada Test Site
Jean		None identified
Valley Modified		None identified

a. Source: TRW (1999k, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.

Table 3-35. Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

Rail corridor	Hydrographic area[a] No.	Hydrographic area[a] Name	Perennial yield (acre-feet)[b,c,d]	Designated Groundwater Basin[e,f]
Caliente				
Caliente to Sand Spring Valley	204	Clover Valley	1,000	No
	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	208	Pahroc Valley	21,000	No
	171	Coal Valley	6,000	No
	172	Garden Valley	6,000	No
Sand Spring Valley to Mud Lake	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, southern part	2,800	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
Mud Lake to Yucca Mountain	142	Alkali Spring Valley	3,000	No
	145	Stonewall Flat	100	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Carlin				
Beowawe to Austin	54	Crescent Valley	16,000	Yes
	138	Grass Valley	13,000	No
Austin to Mud Lake – Via Big Valley	137B	Big Smokey Valley, northern part	65,000	Yes
	137A	Big Smokey Valley and Tonopah Flat	6,000	Yes
Mud Lake to Yucca Mountain	142 to 227A	See Caliente corridor		
Caliente-Chalk Mountain				
Caliente to Sand Spring Valley	204 to 170	See Caliente corridor		
Sand Spring Valley to Yucca Mountain	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Jean				
Jean to Yucca Mountain	165	Jean Lake Valley	50	Yes
	164A	Ivanpah Valley, northern part	700	Yes
	163	Mesquite Valley (Sandy Valley)	2,200	Yes
	162	Pahrump Valley	12,000	Yes
	230	Amargosa Desert	24,000	Yes
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Valley Modified				
Dike Siding (north of Las Vegas) to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, southern part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	Yes
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No

a. Source: Bauer et al. (1996, pages 542 and 543 with corridor map overlay).

b. Source: NDWP (1998, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230 (NDWP 1998, 1999b, hydrographic area 225; NDWP (1999b, hydrographic area 230).

c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.

d. To convert acre-feet to cubic meters, multiply by 1,233.49.

e. Source: NDWP (1999b, Regions 4, 10, 13, and 14).

f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.

g. The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 715,000 cubic meters (580 acre-feet) for the western two-thirds.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-10 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-35 generally come from a single source (NDWP 1998, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (715,000 cubic meters) for the western two-thirds.

3.2.2.1.4 *Biological Resources*

The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

Caliente. From the beginning of the corridor at Caliente to Mud Lake, the Caliente rail corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,900 meters (3,000 to 6,200 feet). The corridor also crosses several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,400 to 1,900 meters (4,600 to 6,200 feet). The Caliente rail corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-22).

The only resident threatened or endangered species in the Caliente rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The only other threatened or endangered species near the corridor is the Federally threatened (State of Nevada protected, Nevada Administrative Code 503.067) Railroad Valley springfish (*Crenichthys nevadae*), which occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (FWS 1996, all).

Four other species classified as sensitive by the Bureau of Land Management occur in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente rail corridor crosses several areas designated as game habitat (BLM 1979, pages 2-27 through 2-36; BLM 1994b, Maps 9 through 13). A bighorn sheep (*Ovis canadensis*) winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline, and the corridor also crosses bighorn sheep habitat west of Goldfield near Stonewall Mountain. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief Mountains, Delamar Mountains, Reveille Range, Kawich Range/Quinn Canyon, Stonewall Mountain, and west of the Worthington Mountains. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Sand Spring, Railroad, Reveille, and Stone Cabin Valleys, and from Mud Lake to Stonewall Mountain. Meadow Valley Wash north of Caliente is classified as habitat for waterfowl.

At least six springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (TRW 1999k, page 3-23). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (BLM 1994b, Maps 14 and 15). The corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The Caliente rail corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 18 and 19). From U.S. Highway 93 to Sand Spring Valley, the corridor passes through a herd management area in the Chief Range. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

Carlin. The Carlin rail corridor crosses Crescent and Grass Valleys, then passes through Big Smokey Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin rail corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-24).

The only resident threatened or endangered species in the Carlin rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin rail corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smokey Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale (NNHP 1997, all). A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1983, Map 3-1; BLM 1994b, Maps 9 to 13; TRW 1999k, page 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, north of Toquima Range near Hickison summit, along most of Big Smokey Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley, in the Simpson Park Range, and at Stonewall Mountain. The corridor crosses bighorn sheep habitat east of Goldfield and at Stonewall Mountain.

Three springs, seven riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (TRW 1999k, page 3-25). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain, west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is 0.2 kilometer (0.1 mile) from the corridor in the south end of Big Smokey Valley. Five of the riparian areas (Skull, Steiner, and Ox Corral creeks, and Water and Rye Patch canyons) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Two of these (Steiner and Ox Corral creeks, both at the south end of Grass Valley) are ephemeral and have little or no riparian vegetation where the route crosses them. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smokey Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (BLM 1983, Map 2-4; BLM 1994b, Maps 18 and 19).

Caliente-Chalk Mountain. The Caliente-Chalk Mountain rail corridor begins near Caliente and is identical to the Caliente rail corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente rail corridor, the Caliente-Chalk Mountain rail corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land

cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert scrub (31 percent), and sagebrush (9 percent).

The only resident threatened or endangered species in the Caliente-Chalk Mountain rail corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Seven species classified as sensitive by the Bureau of Land Management have been found in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Beatley's scorpionweed (*Phacelia beatleyae*) also has been reported at two locations in Yucca Flat. The long-legged myotis (*Myotis volans*, a bat) has been found in Jackass Flats and other bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 9, 10, 11). A bighorn sheep winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief, Delamar, Worthington, and Quinn Canyon mountains. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Areas within 0.4 kilometer (0.25 mile) of springs, seeps, and livestock watering developments in Meadow Valley are classified as crucial areas for quail and portions of the area are classified as habitat for waterfowl.

Three springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (TRW 1999k, page 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States.

The Caliente-Chalk Mountain rail corridor passes through two wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-42 and 2-43; BLM 1994b, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

Jean. The Jean rail corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (TRW 1999k, page 3-28).

The only resident threatened or endangered species in the Jean rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert

tortoises is low (Karl 1980, pages 75 to 87; Rautenstrauch and O'Farrell 1998, pages 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus*), which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean (NNHP 1997, all). No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean rail corridor crosses several areas the Bureau of Land Management designates as game habitat (BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses four areas designated as quail/chukar or quail habitat: at the intersection of State Highway 161, northeast of Goodsprings, south of Potosi Spring, and east of Pahrump. An additional quail habitat area is on the route from the town of Johnnie to Yucca Mountain. Designated mule deer habitat occurs in three places along the corridor: on the southern half of Potosi Mountain, northwest of Goodsprings, and south of the intersection with State Highway 161. Bighorn sheep winter areas occur south of the intersection of the corridor with State Highway 161. Bighorn sheep habitat is in the Wilson Pass area and to the north on Potosi Mountain. The corridor also crosses a potential bighorn sheep migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

Valley Modified. The Valley Modified rail corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; TRW 1999k, page 3-29).

The only resident threatened or endangered species in the Valley Modified rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the Endangered Species Act and as protected under Nevada Administrative Code, has been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (TRW 1999k, page 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, has been introduced into ponds in Floyd Lamb State Park and into

the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (NNHP 1997, all; TRW 1999k, page 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified rail corridor (TRW 1999k, page 3-29; BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all) was used.

Archaeological and Historic Resources. Archaeological data from the five rail corridors, including a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of each corridor, are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno, and at the Harry Reid Center at the University of Nevada, Las Vegas, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified corridors, less than 3 percent of the total area for the Carlin corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain corridor. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain and, therefore, are not included in this EIS.

Records indicate that a number of archaeological sites have been identified along the corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-36 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DOE 1988b, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

Table 3-36. Number of archaeological sites along candidate rail corridors.

Category[a]	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Potentially eligible for nomination					
Temporary camps	--[b]	--	3	--	--
Extractive localities	--	--	3	--	--
Processing localities	--	--	--	--	--
Localities	--	1	16	--	--
Caches	--	--	--	--	--
Stations	--	--	--	--	--
Historic sites	--	--	3	--	--
Unknown type	7	20	3	--	7
Total potentially eligible	*7*	***21***	***28***	*0*	*7*
Not evaluated	29	26	6	2	4
Recorded sites (approximate total)	***97***	***110***	***100***	***6***	***19***

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the Programmatic Agreement.

There is some additional information available for the Carlin corridor. The northern part of this corridor is not well known archaeologically. The central part has been the subject of important archaeological and ethnographic investigations. Elston (1986, all) summarizes the region's prehistory. Archaeological research in Monitor Valley at the Gatecliff Shelter established important chronological data for this part of the Great Basin. In addition, there have been studies of settlement patterns in the Upper Reese River Valley west of the Carlin rail corridor.

Thomas, Pendleton, and Cappannari (1986, all) summarizes ethnographic studies in this region. The Big Smokey Valley, which the Carlin corridor crosses, was part of several ethnographic studies of the Western Shoshone. A part of the Pony Express route crosses the northern end of the Carlin rail corridor.

Native American Interests. Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (AIWS 1998, pages 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.
- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.
- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.

- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

Native Americans live in the vicinity of two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) from the Jean corridor.

- *Valley Modified.* The Las Vegas Paiute Colony is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes and various businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified rail corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified rail corridor.

3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties—Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

Employment. Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 1994, Esmeralda, Eureka, and Lander Counties had average labor forces of about 670, 840, and 3,000, respectively, and average unemployment rates of 7.7, 9.5, and 10 percent (Bureau of the Census 1998, all). During the same year, the per capita income of Esmeralda, Eureka, and Lander Counties was about $33,000, $27,000, and $20,000, respectively (NDETR 1999, all). All three of these counties are small in economic terms and have chronically high unemployment.

Population. Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin rail corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The two block groups that comprise the county had densities of 0.3 and 0.4 person per square mile. The Esmeralda County population projection for 2000 is about 1,400 (NSDO 1998, Esmeralda).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. Density at the block group level ranged from 0 to 5.3 persons per square mile. The projected population of Eureka County for 2000 is about 2,100 (NSDO 1998, Eureka).

The population of Lander County is 56 percent urban and 44 percent rural, with the urban population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The projected population of Lander County for 2000 is about 7,700 (NSDO 1998, Lander).

Housing. Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (Bureau of the Census 1998, Esmeralda). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (Bureau of the Census 1998, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (Bureau of the Census 1998, Lander).

Economy. Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. For the Esmeralda, Eureka, and Lander portions of the Carlin corridor. Esmeralda, Eureka, Lander, and Nye are very small counties in economic terms. Esmeralda County is particularly small, smaller even than Lincoln County in earnings and employment. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

Public Services. Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. Public services (for example, hospitals, libraries, community centers) are available in small communities in the counties (for example, Battle Mountain, Ely, Eureka). Community water and sewer services are available in small communities; wells and septic tanks serve outlying areas.

3.2.2.1.7 *Noise*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

Caliente. Most of the Caliente corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-30), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Goldfield, Panaca, and Caliente (Table 3-30).

Carlin. The Carlin rail corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smokey Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle

Mountain (Table 3-30). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

Caliente-Chalk Mountain. Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau of Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Jean. The Jean rail corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Valley Modified. The Valley Modified rail corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury. Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (Brown-Buntin 1997, page 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-30). Noise levels in Indian Springs and Mercury probably range from 45 to 55 dBA (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

Caliente. Section 3.2.2.1.4 describes the environmental setting along the Caliente corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Carlin. Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las

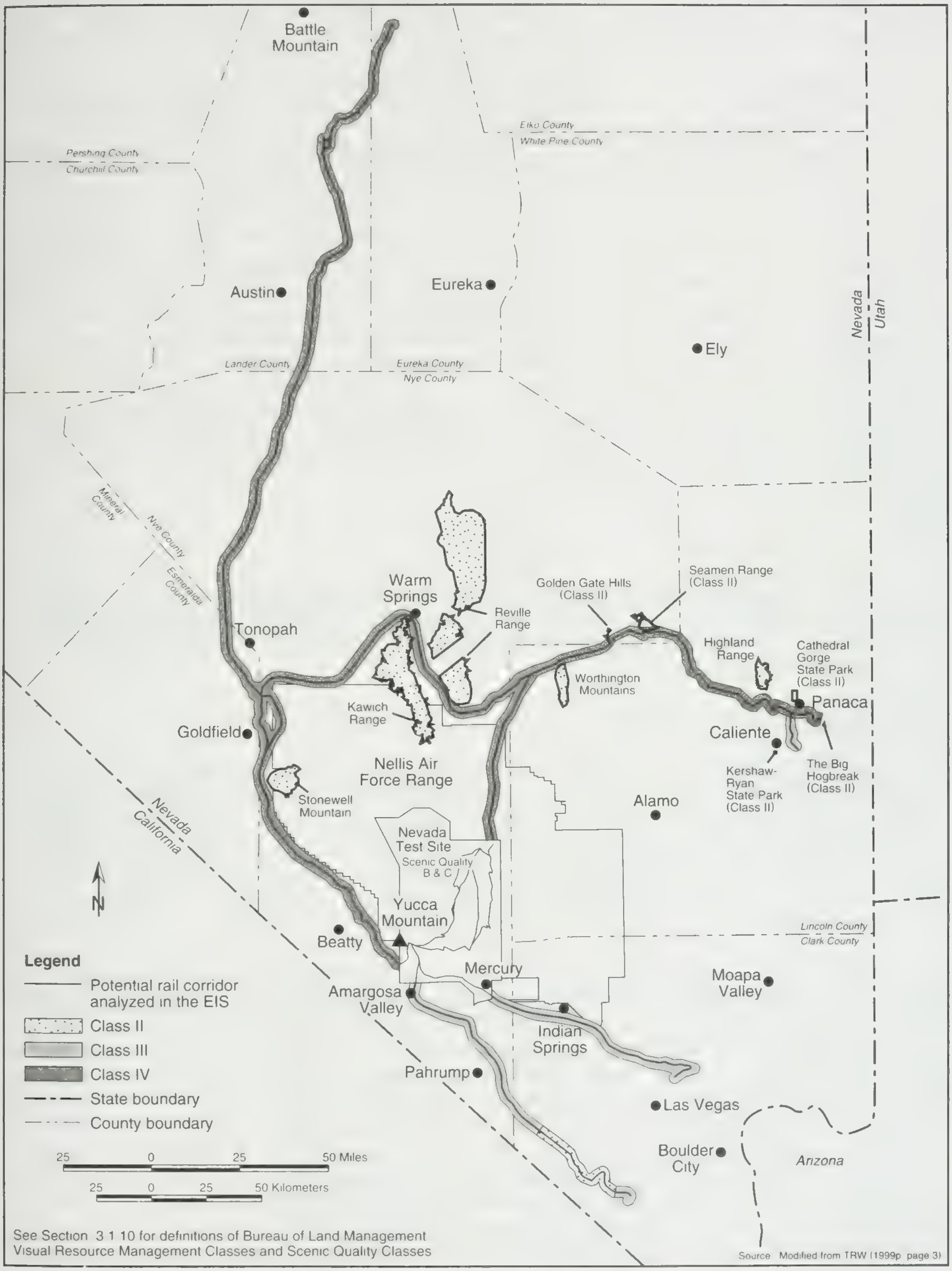


Figure 3-25. Visual Resource Management classes along the potential rail corridors.

Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Caliente-Chalk Mountain. Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk mountain corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-25). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

Jean. Section 3.2.2.1.4 describes the environmental setting of the Jean corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass alternate passes through Class II land in Goodsprings Valley, but the rest of the route and west of the Stateline Pass secondary corridor cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Valley Modified. Section 3.2.2.1.4 describes the environmental setting of the Valley Modified corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye). The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

In 1990, the minority population (White Hispanic, Black, Asian Pacific Islander, American Indian/Eskimo/Aleut, and Other) of Esmeralda County was about 210, or 15 percent of the population. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992e, Tables P8 and P12). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992e, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 1990, the minority population of Eureka County was about 170 persons, or 11 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992f, Tables P8 and P12). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992f, Table P117).

In 1990, the minority population of Lander County was about 1,100 persons, or 17 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992g, Tables P8 and P12). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992g, Table P117).

Tables 3-37 and 3-38 list by county the number of census block groups with high minority and low-income populations, respectively, that the rail corridors pass through or near. Table 3-39 lists the number of census block groups with high minority populations, high low-income populations, or both that each rail corridor could affect. More than 300 block groups in the City of Las Vegas have either low-income or minority populations. However, the rail corridors do not intersect any of these block groups.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the rail corridors do not intersect any of these block groups.

Table 3-37. High minority population census block groups near or crossed by rail corridors.

County	Crosses	Near
Eureka	0	0
Lander	0	0
Nye	0	1[a]
Esmeralda	0	0
Clark[b]	2	2
Lincoln	0	0

a. This block group is also a high low-income population block group included in Table 3-39.
b. Outside Las Vegas.

Table 3-38. High low-income population census block groups near or crossed by rail corridors.

County	Crosses	Near
Eureka	0	0
Lander	0	0
Nye	2	3[a]
Esmeralda	0	0
Clark[b]	0	0
Lincoln	0	0

a. One block group is also a high minority population block group included in Table 3-39.
b. Outside Las Vegas.

Table 3-39. High minority and high low-income population census block groups near or crossed by rail corridors.

Corridor	Minority	Low-income	Minority and low-income
Caliente	0	2 near, 3 crossed[a]	0
Carlin	0	2 crossed[a]	1 near[a]
Caliente-Chalk Mountain	0	0	0
Jean	0	1 near[a]	0
Valley Modified	2 crossed[b]	0	0

a. In Nye County.
b. In Clark County outside Las Vegas.

3.2.2.2 Heavy-Haul Truck Route and Intermodal Transfer Station Environmental Baseline

This section discusses the environmental characteristics of counties and land areas that could be affected by the construction and operation of an intermodal transfer station and the operation of heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository on Nevada highways. The discussion describes existing environmental conditions in the candidate areas where an intermodal transfer station could be located along Nevada highway routes that could be used for the heavy-haul truck transportation of casks containing spent nuclear fuel and high-level radioactive waste. The candidate locations for an intermodal transfer station are near the communities of Caliente, Sloan, and Jean, and northeast of Las Vegas near Dry Lake on the Union Pacific Railroad Valley siding. These locations can be grouped into three general sites near existing rail lines and highways: near Caliente

(Caliente), southeast of Las Vegas (Sloan/Jean), and northeast of Las Vegas (Apex/Dry Lake). DOE is considering more than one site for the station in each general area.

The heavy-haul trucks would use existing highways that would be upgraded as necessary to accommodate such vehicles. There are five potential heavy-haul routes. Three of these routes (Caliente, Caliente-Chalk Mountain, and Caliente-Las Vegas) are associated with the Caliente intermodal transfer station site. The Sloan/Jean and Apex/Dry Lake intermodal transfer station sites are associated with one candidate route each.

To define the existing (or baseline) environment associated with the three candidate intermodal transfer station locations and along the five candidate heavy-haul truck routes, DOE has compiled environmental information for each of the following subject areas.

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.2.1)
- *Air quality and climate:* The quality of the air and climate (Section 3.2.2.2.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.2.3)
- *Biological resources:* Important biological resources (Section 3.2.2.2.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.2.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.2.6)
- *Noise:* The existing noise environments (Section 3.2.2.2.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.2.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.2.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.2.10)
- *Existing traffic on potential routes for heavy-haul trucks:* Existing traffic in terms of level of service (on the five alternative heavy-haul routes for trucks) (Section 3.2.2.2.11)

The HIGHWAY computer program (Johnson et al. 1993a, all) provided population distributions for the different population zones (urban, rural, and suburban) along the alternative highway routes for heavy-haul trucks. This approach, which Chapter 6 and Appendix J describe in detail, is consistent with the national transportation analysis. DOE expects the waste quantities generated by intermodal transfer station construction to be small in comparison to those from repository construction and operation. Therefore, this discussion does not include existing waste disposal infrastructure along the routes.

DOE evaluated potential impacts of the implementing alternatives in the region of influence for each of the following subject areas. Table 3-40 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to heavy-haul infrastructure construction and operations.

Table 3-40. Regions of influence for heavy-haul implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or for which ownership or use would change as a result of construction and use of an intermodal transfer station and associated highway route
Air quality and climate	The Las Vegas Valley for implementing alternatives in which the construction and operation of an intermodal transfer station and associated heavy-haul route could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during construction and operations
Hydrology	*Surface water:* areas where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that would be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and that could be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands, that could be disturbed by construction and operation of an intermodal transfer station and associated heavy-haul route; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flow
Cultural resources	Land areas that would be disturbed by the construction and operation of an intermodal transfer station and associated heavy-haul route
Socioeconomic environments	Clark, Lincoln, Nye, and other counties that a route for heavy-haul vehicles could traverse
Occupational and public health and safety	800 meters[a] on each side of the route for heavy-haul vehicles for incident-free transportation, 80-kilometer[b] radius for potential impacts from accidents
Noise	Inhabited commercial and residential areas where noise from the construction and operation of an intermodal transfer station and associated routes for heavy-haul vehicles could be a concern
Aesthetics	The landscapes along potential routes for heavy-haul vehicles and at potential locations for intermodal transfer station where aesthetic quality could be affected by construction and operation
Utilities energy, and materials	Local, regional, and national supply infrastructure that would be required to support construction and operation of an intermodal transfer station and associated route for heavy-haul vehicles
Environmental justice	Varies with the individual resource area

a. 800 meters = 0.5 mile.
b. 80 kilometers = 50 miles.

Caliente. DOE has identified two locations for an intermodal transfer station southwest of the City of Caliente. Table 3-41 lists the ownership of the land involved. Both sites would use a local road to provide access to U.S. 93, the starting point for all three of the heavy-haul routes associated with this intermodal transfer station. Both parcels being considered are in the Rainbow Canyon section of Meadow Valley Wash. This canyon is used for a variety of recreational purposes and is the route of the Union Pacific railroad. Kershaw-Ryan State Park is across Meadow Valley Wash about 0.4 kilometer (0.25 mile) east of the station sites (DOE 1998j, all). The northern parcel includes a wastewater treatment plant.

3.2.2.2.1 *Land Use and Ownership*

This section describes existing land use and ownership for the candidate intermodal transfer station locations and for the candidate heavy-haul routes. Table 3-41 summarizes the estimated land commitment for each site at the three candidate locations. The following paragraphs describe the candidate intermodal transfer station sites.

Table 3-41. Estimated land commitment areas for candidate intermodal transfer station sites (square kilometers).[a,b]

	Commitment		
		Percentage current ownership or control[c]	
Potential location	Total area	BLM	City of Caliente[d]
Caliente			
North Site	0.5		100
South Site	0.25		100
Sloan/Jean			
North Site	3.3	100	
Middle Site	3.1	100	
South Site	1	100	
Apex/Dry Lake			
North Site	3.5	100	
South Site	1	100	

a. Source: TRW (1999d, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Bureau of Land Management property is public land administered by the Bureau.
d. "City of Caliente" designates patented land owned by the city. A small undesignated portion of both Caliente sites is Bureau of Land Management land.

Sloan/Jean. DOE has identified three possible parcels in the area of Sloan and Jean for potential use as the location of an intermodal transfer station. Each provides adequate land area adjacent to the Union Pacific mainline and has access to existing roadways. Figure 2-29 in Chapter 2 shows these sites. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in the *Proposed Las Vegas Resource Management Plan and Environmental Impact Statement* (BLM 1998, all).

Apex/Dry Lake. DOE has identified two land parcels near the intersection of U.S. 93 and Interstate 15 at the Apex and Dry Lake areas northeast of Las Vegas for the possible location of an intermodal transfer station. Both provide adequate land area close to the Union Pacific mainline and have access to existing roadways. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in BLM (1998, all). The Moapa Indian Reservation is about 5 kilometers (3 miles) north of the proposed station site. The Dry Lake solar enterprise zone is almost 5 kilometers west of the site (DOE 1996f, page 4-227). The Apex industrial complex is about 16 kilometers (10 miles) to the southwest. Tenants at the complex include Kerr-McGee Chemical Corporation, Chemstar Inc., and Georgia Pacific Corporation. Silver State Disposal operates a waste landfill and waste-processing facilities east of I-15 about 5 kilometers south of the southernmost site.

Routes for Heavy-Haul Trucks. The five possible routes that heavy-haul trucks could use in Nevada—Caliente, Caliente-Las Vegas, Caliente-Chalk Mountain, Sloan/Jean, and Apex/Dry Lake—have existing highways in established rights-of-way. The routes use combinations of highways that, after improvement, heavy-haul trucks could use to travel from an intermodal transfer station at a mainline railroad to the repository.

3.2.2.2.2 *Air Quality and Climate*

This section summarizes existing air quality and climate conditions for each of the candidate intermodal transfer station sites and the five candidate heavy-haul routes.

Air Quality. Both the Caliente and Apex/Dry Lake sites are in areas that are either unclassified or in attainment for criteria pollutants (Fosmire 1999, all). The northern portion of the Sloan/Jean site is in the Las Vegas nonattainment area (Fosmire 1999 all; EPA 1999c, all). There are no State of Nevada air

quality monitoring stations at or near either the Caliente or Apex Dry Lake site (NDCNR 1999, pages A1-1 through A1-9). Clark County operates a particulate matter (PM_{10}) monitoring station at Jean.

The Caliente and Caliente-Chalk Mountain heavy-haul routes both pass through rural parts of Nevada. These areas are either unclassifiable or in attainment for criteria pollutants. The air quality in these areas is good. There are no State of Nevada air quality monitoring stations along these routes (NDCNR 1999, pages A1-1 through A1-9). These statements are also true for the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes before they enter and after they leave the Las Vegas Valley.

The air quality in the segments of the Caliente-Las Vegas, Sloan/Jean, and Apex Dry Lake routes that pass through the Las Vegas Valley and extend part of the way to Indian Springs is in serious nonattainment for particulate matter (PM_{10}) (EPA 1999c, Region 9 PM_{10} Nonattainment Areas). Clark County adopted a plan for demonstrating PM_{10} attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. In addition, the Las Vegas Valley is in serious nonattainment for carbon monoxide. Efforts are being made to bring the area into attainment status.

Climate. This section describes the climate affecting the candidate intermodal transfer station sites and heavy-haul routes.

The community of Caliente and the site of the proposed intermodal transfer station are in Meadow Valley Wash, a relatively narrow canyon that trends to the northeast. Small canyons enter Meadow Valley Wash from the east and west. The diurnal cycle of up-canyon winds during the daytime and down-canyon winds at night minimizes periods of calm conditions. The community of Caliente is about 1,300 meters (4,300 feet) above sea level. Average annual precipitation is about 22 centimeters (9.0 inches); average snowfall is about 35 centimeters (14 inches) (TRW 1997a, page A-14). The maximum single-day precipitation record is 5.4 centimeters (2.1 inches). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime. The mean maximum July temperature is 35°C (95°F), and the mean minimum January temperature is −8.2°C (18°F) (TRW 1997a, page A-14).

The climate at the Sloan/Jean and Apex/Dry Lake station sites is similar to Las Vegas (TRW 1997a, Section 4.1; Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Precipitation in Las Vegas averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare. Occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime. The maximum recorded daily precipitation is 6.6 centimeters (2.6 inches). The mean maximum July temperature is 40°C (104°F), and the mean minimum January temperature is 0.9°C (33°F).

The Caliente and Caliente-Chalk Mountain heavy-haul routes, and to a lesser extent the Caliente-Las Vegas route, cross mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nevada the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches) in central White Pine and Nye Counties; annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). The southern portion of the Caliente-Las Vegas route, through Clark County, is at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Along all three of these routes, occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime.

The Sloan/Jean and Apex/Dry Lake heavy-haul routes are at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). However, occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime.

3.2.2.2.3 *Hydrology*

This section describes hydrologic conditions in terms of surface water and groundwater near the candidate intermodal transfer stations and along the candidate heavy-haul shipment routes.

3.2.2.2.3.1 Surface Water. DOE studied each of the candidate intermodal transfer station sites and associated highway routes for their proximity to sensitive environmental resources (TRW 1999k, Appendixes J, K, L, M, N, and O), including surface waters and riparian lands. Table 3-42 summarizes potential surface-water-related resources within a 1-kilometer (0.6-mile) region of influence from the station sites and highway routes that heavy-haul trucks would use. The table lists surface-water-related resources associated with the Caliente intermodal transfer station site and with each of the potential routes starting at that site. No surface-water-related resources were identified in the region of influence for either the Sloan/Jean or Apex/Dry Lake station site, and none were identified along the associated routes.

Intermodal Transfer Station Locations

Caliente. Flood Insurance Rate Maps published by the Federal Emergency Management Agency address the area in Meadow Valley Wash south of Caliente where the two proposed sites for the Caliente intermodal transfer stations are located. The maps (FEMA 1988a, all; FEMA 1988b, all) show two areas on the west side of the Union Pacific rail tracks that match up with the proposed sites. Both areas are outside the inundation boundary of the 100-year flood, but within the boundary of the 500-year flood.

Sloan/Jean. Based on Flood Insurance Rate Maps, the southernmost site proposed for the Jean intermodal transfer station (on the west site of the Union Pacific rail tracks) would be in the same general area as a 100-year flood inundation zone. The flood map (FEMA 1995a, all) shows three separate washes or drainage areas that originate in the area northwest of the intersection of State Route 161 (or State Route 53 on the map) and I-15. From their origins, the washes drain to the southeast, beneath I-15, and join a southwest drainage that parallels the rail tracks until it reaches the Roach Lake area to the south. The southern Jean intermodal transfer station site is in the area where the first southeast-draining channel curves around into a southwest-draining channel. The 100-year flood inundation areas appear to be about 150 meters (500 feet) wide for these drainage channels.

The northern site proposed for the Jean intermodal transfer station is on the east side of the tracks in an area where the map shows no inundation lines (FEMA 1995a, all). In fact, the map identifies this area with a Zone X designation, indicating it is outside the 500-year floodplain.

According to the Federal Emergency Management Agency Map Index for Clark County, Nevada, and Incorporated Areas (FEMA 1995b, all), the northernmost site for this area, the Sloan intermodal transfer station site, is in an area (Panel 32003C2925 D) with no printed map. The Map Index further describes these unprinted areas as Zone X, indicating they are outside the 500-year floodplain.

Apex/Dry Lake. Based on the Flood Insurance Rate Map for the area of the Apex/Dry Lake intermodal transfer station sites (FEMA 1995c, all), both proposed locations are outside any 100-year flood zone. The nearest flood zone identified on the map is for the Dry Lake area west of the sites. At its closest, the inundation area approaches to within about 300 meters (1,000 feet) of I-15, but the intermodal transfer station site would be on the other side (east side) of I-15. The northern site would appear to be at least

Table 3-42. Surface-water-related resources at potential intermodal transfer station sites and along candidate routes for heavy-haul trucks.[a]

Station or route	Distance from station or route (kilometers)[b]	Feature
Caliente station	0.5	Spring – unnamed spring, southwest of Caliente and northwest of station site
	0.2	Riparian/stream – perennial stream and riparian habitat along Meadow Valley Wash
Caliente route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Tonopah)	0.2	Springs – Twin Springs, 15 kilometers east of Warm Springs
	Within - 0.2	Springs – Warm Springs, group of thermal springs near town of Warm Springs, outflow crosses the route
	0.4	Spring – Fivemile Spring in Stone Cabin Valley
	1.0	Spring – Rabbit Spring, west of Goldfield
	0.1	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.3	Spring – unnamed, in upper Oasis Valley
	0.4	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.4	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.4	Spring – Fleur-de-lis Spring at Springdale
	0.1	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.1	Spring – unnamed, east of U.S. 95 north of Beatty
	0.9	Spring – unnamed, east of U.S. 95, north of Beatty
	0.9	Spring – Gross Spring, east of U.S. 95, north of Beatty
	Within	River – Amargosa River, parallels U.S. 95 for about 23 kilometers near Beatty
	0.2 - 0.3	Springs – group of thermal springs on east border of U.S. 95, north of Beatty
	0.3	Spring – Well Spring, west of U.S. 95, north of Beatty
	0.4	Spring – Ute Spring, north of Beatty
	0.6	Spring – unnamed, west of U.S. 95, north of Beatty
	0.3	Spring – Revert Spring in Beatty
	0.3	Spring – unnamed, east of U.S. 95, south of Beatty
Caliente-Chalk Mountain route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.4	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	0.9	Spring – Cane Spring, north of Skull Mountain on Nevada Test Site
Caliente-Las Vegas route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.4	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to I-15 (via U.S. 93)	0.7	Spring – Pedretti Seeps, 3.5 kilometers southeast of Crystal Springs
	0.7	Spring – unnamed, west of route, just south of Pedretti Seeps
	0.8	Spring – Deacon Spring, 5 kilometers southeast of State Highway 375
	1.0	Spring – Brownie Spring, 5 kilometers southeast of State Highway 375
	0.1	Spring – Ash Springs, 7 kilometers southeast of State Highway 375, flows under road
	0.7	Spring – Grove Spring, 1.5 kilometers north of Upper Pahranagat Valley
	0.1	Lakes – route parallels Upper and Lower Pahranagat lakes and associated inundated areas (marshes) for about 15 kilometers
	0.1	Spring – unnamed, 0.2 kilometers west of U.S. 93 and Maynard Lake
	0.1	Lake – Maynard Lake, route borders for about 1 kilometer
	0.8	Spring – Coyote Springs, 21.5 kilometers north of junction with State Route 168
U.S. 93/I-15 junction to U.S. 95 (via the proposed northern beltway)		None
U.S. 95 to Yucca Mountain		None
Sloan/Jean station		None identified
Sloan/Jean route		None identified
Apex/Dry Lake station		None identified
Apex/Dry Lake route		None identified

a. Source: TRW (1999k, Appendixes J, K, L, M, N, and O).
b. To convert kilometers to miles, multiply by 0.62137.

300 meters from the inundation zone. Both areas are in Zone X (determined to be outside the 500-year floodplain).

Highway Routes for Heavy-Haul Trucks

Potential hydrologic hazards along a heavy-haul route include flash flooding and debris flow. All routes have potential flash flooding concerns. However, because of the required road upgrades, the robustness of the vehicle and shipping cask, and the en route safeguards (for example, escorts), flash flooding or standing water is not expected to be a serious threat to heavy-haul shipments.

3.2.2.2.3.2 Groundwater. As discussed in relation to the potential rail corridors, all of Nevada has been divided into groundwater basins and sub-basins, with these latter, smaller divisions termed hydrographic areas. The water resource planning and management information generated by the State of Nevada for these hydrographic areas provides the basis for groundwater information presented for both intermodal transfer station locations and the candidate highway routes that would be used by heavy-haul trucks. The following paragraphs provide an overview of the groundwater conditions at these sites and along the associated routes. Water demand at an intermodal transfer station would be small for both construction and operations. Water needs during operations would consist primarily of the needs of the personnel that staff the station. Water needs for construction and operations would be met by trucking water to the site, installing a well, or possibly by connection to a local water distribution system. This demand would be unlikely to cause noticeable change in water consumption rates for the area. Consequently, no baseline water-use information is provided.

Intermodal Transfer Station Locations

Caliente. The two sites southwest of Caliente being considered for the intermodal transfer station are close to one another and are located in Nevada's Colorado River Basin (designated Hydrographic Region 13). This hydrographic region covers about 32,000 square kilometers (12,000 square miles) and parts of four counties (NDWP 1999b, Region 13). The Colorado River Basin is further divided into 27 hydrographic areas including Lower Meadow Valley Wash (Area 205), where the Caliente sites are located. This area has been assigned a "Designated Groundwater Basin" status, which means that its permitted water rights approach or exceed the estimated perennial yield and its water resources are being depleted or require additional administration. The additional administration normally includes a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.) for the groundwater from this area.

Sloan/Jean. The Jean sites being considered for the intermodal transfer station are in Nevada's Central Hydrographic Region (also designated Region No. 10). This is the largest hydrographic region in Nevada, encompassing about 120,000 square kilometers (46,000 square miles) and parts of 13 counties (NDWP 1999b, Region 10). The Central Region has 90 hydrographic areas and sub-areas, including Ivanpah Valley Northern Part (Area 164A), where the Jean sites are located. This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater in the vicinity of the candidate Jean sites is approximately 150 meters (490 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

The site near Sloan being considered for the intermodal transfer station is in Nevada's Colorado River Basin (Hydrographic Region 13), as described for the Caliente sites. The Sloan site is in the hydrographic area designated Las Vegas Valley (Area 212). This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater at Sloan is approximately 240 meters (790 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

Apex/Dry Lake. The two sites near Apex Dry Lake being considered for the intermodal transfer station are close to one another and are in Nevada's Colorado River Basin, as described for the Caliente sites.

The Apex Dry Lake sites are in the hydrographic area designated Garnet Valley (Area 216). The estimated perennial yield for the groundwater in this area is only 490,000 cubic meters (400 acre-feet), but it is not a Designated Groundwater Basin. The depth to groundwater at Apex Dry Lake is about 60 meters (200 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

Highway Routes for Heavy-Haul Trucks

The highway routes in Nevada that heavy-haul trucks could use cross through several hydrographic regions and a greater number of hydrographic areas. To identify groundwater that could potentially be affected, a map of these hydrographic areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed highway routes to get a reasonable approximation of the areas that would be crossed. The results of this effort are listed in Table 3-43. This table also lists estimates of the perennial yield for each of the hydrographic areas crossed and if the area is a Designated Groundwater Basin. Basins with this designation are the areas where additional water demand would be most likely to adversely affect local groundwater resources. None of the candidate routes would totally avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain route would cross only two designated basins: one in the Lower Meadow Valley Wash at the beginning of the route and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain routes split.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11. For simplicity, the perennial yield values listed in Table 3-43 generally come from a single source (NDWP 1998, Regions 10, 13, and 14) and, therefore, are not ranges of values. The hydrographic areas in the vicinity of Yucca Mountain (that is, Areas 225 through 230) are the exception to perennial yield values coming from the single source. The perennial yield values for these areas come from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values presented in that document.

3.2.2.2.4 *Biological Resources*

The existing biological environments described in this section includes the areas inside the boundaries of the intermodal transfer station sites and within 100 meters (about 330 feet) of the centerline of the heavy-haul routes. It also includes springs within 400 meters (0.25 mile) of the intermodal transfer sites and the routes. The section discusses environmental settings and important biological resources for each candidate station and associated heavy-haul routes. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

Caliente Intermodal Transfer Station

The 0.7-square kilometer (170-acre) area DOE is considering for the Caliente intermodal transfer station is about 1 kilometer (0.6 mile) southwest of Caliente and less than 500 meters (1,600 feet) west of Meadow Valley Wash. This area is at an elevation of about 1,200 meters (3,900 feet). The land cover types at this site are primarily agricultural—pasture, 88 percent, and salt desert scrub, 12 percent.

No species classified as Federally threatened or endangered, as State protected, or as sensitive by the Bureau of Land Management occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by Bureau of Land Management, the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker (*Catostomus clarki* ssp.), occur in the adjacent Meadow Valley Wash (NNHP 1997, all). Nevada also classifies the Meadow Valley Wash desert sucker as sensitive.

Table 3-43. Hydrographic areas (groundwater basins) crossed by candidate routes for heavy-haul trucks.[a]

Route	Hydrographic area Number	Hydrographic area Name	Perennial yield[b,c] (acre-feet)[d]	Designated groundwater basin[e,f]
Caliente				
Caliente to Crystal Springs (near Hiko)	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	182	Delamar Valley	3,000	No
Crystal Springs to Rachel	209	Pahranagat Valley	25,000	No
	169A	Tikaboo Valley, Northern Part	1,300	No
Rachel to Yucca Mountain (via Tonopah)	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, Southern Part	2,800	No
	173B	Railroad Valley, Northern Part	75,000	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
	137A	Tonopah Flat	6,000	Yes
	142	Alkali Spring Valley	3,000	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	230	Amargosa Valley	24,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente-Chalk Mountain				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs to Rachel	209 to 170	See Caliente Route		
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	170			
	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente-Las Vegas				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs (near Hiko) to U.S. 93/I-15 junction at Dry Lake	209			
	210	Coyote Springs Valley	18,000	Yes
	217	Hidden Valley	200	No
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216	Garnet Valley	400	No
U.S. 95 junction to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, Southern Part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	No
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Sloan/Jean[h]				
Jean to U.S. 95 junction	164A	Ivanpah Valley, Northern Part	700	Yes
	165	Jean Lake Valley	50	Yes
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		
Apex Dry Lake				
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216 to 212	See Caliente-Las Vegas route		
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		

a. Source: Bauer et al. (1996, pages 542 and 543 with route map overlay).
b. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Source: NDWP (1998, Regions 10, 13, and 14); for Hydrographic Areas 225 through 230 the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet for the combined area of hydrographic areas 225 through 230 (NDWP 1998, all; NDWP 1999a, page 9).
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. "Yes" indicates that the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
f. Source: NDWP (1999b, Regions 10, 13, and 14).
g. The perennial yield value shown for Area 227A is the lowest estimated value in Thiel (1997, page 8), and is accompanied by the additional qualification: 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.
h. The hydrographic areas listed for the Sloan/Jean Route are based on the intermodal transfer station located at Jean. For the Sloan location, the route would begin with Hydrographic Area 212, then proceed as shown.

There is no designated game habitat in this area, but the adjacent Meadow Valley Wash is classified as important habitat for Gambel's quail (BLM 1979, pages 2-34 and 2-35).

There are no springs at the proposed station location, but moist areas in the proposed station location might be wetlands (TRW 1999k, pages 3-35 and 3-36). The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as a wetlands or other waters of the United States, although there has been no formal wetlands delineation.

Caliente Route. This route passes through the southern Great Basin Desert from the beginning of the route in Caliente to near Beatty. From south of Beatty to Yucca Mountain, the route passes through the Mojave Desert. The predominant land cover types along the entire route are salt desert scrub (49 percent), sagebrush (14 percent), and creosote-bursage (13 percent).

Three threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente heavy-haul route. The Hiko White River springfish (*Crenicthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16), which is about 75 meters (250 feet) south of State Route 375 near the intersection with U.S. 93. The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). A population of the Railroad Valley springfish (*Crenicthys nevadae*, Federal threatened) has been introduced into Warm Springs, the outflow of which crosses U.S. Highway 6 (FWS 1996, page 20). The southern part of the route, along U.S. 95 from Beatty to Yucca Mountain, is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative number of tortoises in this area is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Six species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace (*Rhinichthys osculus velfier*) occurs in Crystal Springs. The Railroad Valley tui chub (*Gila bicolor* ssp 7) (also classified as sensitive by Nevada) occurs in Twin Spring Slough along State Route 375. The Amargosa toad (*Bufo nelsoni*) and the Oasis Valley speckled dace (*Rhinichthys osculus* ssp 1) (both also classified as protected by Nevada) occur in the Amargosa River and elsewhere in the Oasis Valley. Two bats, the Townsend's big-eared bat (*Corynorhinus townsendii*) and fringed myotis (*Myotis thysanodes*), have been documented near the southern end of the route, and other bats classified as sensitive by the Bureau of Land Management might occur near the route. The chuckwalla lizard (*Sauromalus obesus*) also might occur in suitable habitat along the southern end of the route.

This route crosses eight areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Portions of Meadow Valley Wash are designated important habitat for Gambel's quail (*Callipepla gambelii*) and waterfowl. The route crosses mule deer habitat in Newman Canyon, in the Pahroc Range, in the Pahranagat Range, and northwest of the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range, and pronghorn habitat northwest of the Groom Range and from west of Sand Spring Valley through Railroad, Stone Cabin, and Ralston Valleys.

Nineteen springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be considered wetlands or other waters of the United States under Section 404 of the Clean Water Act, although no formal wetlands delineation has been conducted. The route is adjacent to Meadow Valley Wash at the proposed location of the intermodal transfer station. There is an unnamed spring near U.S. 93 west of Caliente. Crystal Spring and its outflow are about 10 meters (33 feet) from State Route 375, which also passes within 250 meters (820 feet) of Twin and Warm Springs and crosses their outflows. Fivemile Spring is about 0.4 kilometer from U.S. 6 in Stone Cabin Valley. U.S. 95 passes within 0.4 kilometer of 12 springs or groups of springs in the Oasis Valley and along the Amargosa River, and crosses the

Amargosa River at Beatty. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route also borders the Bureau of Land Management Oasis Valley Area of Critical Environmental Concern, which is designed to protect riparian areas and sensitive species in Oasis Valley south of Springdale (TRW 1999k, page 3-32).

Caliente-Chalk Mountain Route. From Caliente to Crystal Springs, this heavy-haul route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Rachel the route crosses Hancock Summit and Tikaboo Valley at elevations ranging from about 1,300 to 1,700 meters (4,300 to 5,600 feet). From Rachel to Yucca Mountain the route passes through Sand Spring and Emigrant Valleys, and Yucca Flat, Frenchman Flat, and Jackass Flats, at elevations from 1,700 to 1,900 meters (5,600 to 6,200 feet). Along the entire route, the predominant land cover types are salt desert scrub (37 percent), blackbrush (16 percent), sagebrush (11 percent), and creosote-bursage (10 percent).

Two resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Chalk Mountain heavy-haul route. The Hiko White River springfish (*Crenichthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16). The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). The part of the route from the northern end of Frenchman Flat to Yucca Mountain is within the range of the desert tortoise (Rautenstrauch, Brown, and Goodwin 1994, all). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative abundance of tortoises in this area is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three species classified as sensitive by the Bureau of Land Management occur within 100 meters (about 330 feet) of this route (NNHP 1997, all). The Pahranagat speckled dace occurs in Crystal Springs, Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) occurs in a number of locations in Yucca Flat on the Nevada Test Site, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of bats classified as sensitive by the Bureau of Land Management might occur along the route and the southern end of the route is within the range of the chuckwalla.

This route crosses six areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Meadow Valley Wash is designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in four areas: west of Caliente, near Pahroc Summit Pass, in the Pahranagat Range, and in the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range.

Three springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be wetlands or other waters of the United States under Section 404 of the Clean Water Act, including Meadow Valley Wash, an unnamed spring near U.S. 93 west of Caliente, and Crystal Springs and its outflow. No formal wetlands delineation has been conducted along this route. This route also crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

Caliente-Las Vegas Route. From Caliente to Crystal Springs, this candidate route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Las Vegas, the route parallels the White River through Pahranagat Valley, and then through Coyote Springs, Hidden, Dry Lake, Las Vegas, Mercury, and Rock Valleys, and crosses Jackass Flats to Yucca Mountain. Elevations along the

section from Crystal Springs to Yucca Mountain range from 610 to 1,200 meters (2,000 to 3,900 feet). Along the route the predominant land cover types are creosote-bursage (62 percent) and Mojave mixed scrub (16 percent).

Three resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Las Vegas heavy-haul route. The section of the route from about Alamo to Yucca Mountain is within the range of the threatened desert tortoise (Bury and Germano 1994, pages 57 to 72). An approximately 100-kilometer (60-mile) section of U.S. 93 from Maynard Lake south to a point approximately 6 kilometers (4 miles) north of I-15 is critical habitat for the desert tortoise (50 CFR 17.95). The relative abundance of desert tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The White River springfish (*Crenichthys baileyi baileyi*, Federally endangered and Nevada protected) has been found in Ash Springs, less than 100 meters from U.S. 93 in northern Pahranagat Valley (FWS 1998, pages 12 to 14). The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). The Pahranagat roundtail chub (*Gila robusta jordani*, Federally endangered and Nevada protected) occurs in Ash Springs, the outflow, and throughout Pahranagat Creek, but now is restricted to an approximately 3.5-kilometer (2.2-mile) length of Pahranagat Creek and approximately 2.5 kilometers (1.6 mile) of irrigation ditch in the area (FWS 1998, pages 11 to 12).

Nine other species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace occurs in Ash Springs. The Pahranagat pebblesnail (*Fluminicola merriami*), Pahranagat naucorid (*Pelocoris shoshone shoshone*), and the grated tryonia (*Tryonia clathrata*) occur in Ash Springs, and the Pahranagat Valley montane vole (*Microtus montanus fucosus*) has been observed near the route in Pahranagat National Wildlife Refuge. In addition, pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs along U.S. 93 north of I-15, Ripley's springparsley and Parish's scorpionweed (*Phacelia parishii*) occur adjacent to Jackass Flats Road in eastern Rock Valley, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of other bats classified as sensitive by the Bureau of Land Management occur along the route and most of the route south from Pahranagat Valley is within the range of the chuckwalla and gila monster (*Heloderma suspectus*).

Seven springs, streams, or lakes less than 0.4 kilometer (0.25 mile) from the route might be classified as wetlands under Section 404 of the Clean Water Act, including Meadow Valley Wash, Ash Springs and its outflow, unnamed springs on U.S. 93 west of Caliente and near Maynard Lake, Upper and Lower Pahranagat lakes and their associated marshes, and Maynard Lake. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route crosses eight areas designated as game habitat (BLM 1979, pages 2-26 to 2-35; BLM 1998, Maps 3-7 to 3-9). Meadow Valley Wash and much of Pahranagat Valley are designated as habitat for Gambel's quail and waterfowl, and areas along U.S. 93 north of I-15 are designated as quail habitat. U.S. 93 crosses mule deer habitat west of Caliente and around Maynard Lake, two bighorn sheep migration routes, and crucial bighorn sheep habitat north of the U.S. 93 and I-15 junction.

Sloan/Jean Station and Route

The area that DOE is considering for the Sloan/Jean intermodal transfer station is in Ivanpah Valley. DOE is considering three sites in this valley: southwest of Sloan [3.2 square kilometers (800 acres)], northeast of Jean [3 square kilometers (750 acres)], and east of Jean [1 square kilometer (250 acres)]. These sites are at an elevation of about 910 meters (3,000 feet) and have vegetation typical of the Mojave Desert. The predominant land cover type is creosote-bursage (97 percent). Elevations along the

associated Sloan/Jean heavy-haul route range from about 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along the route include creosote-bursage (78 percent), Mojave mixed scrub (12 percent), and urban development (9 percent).

The three sites that DOE is considering for the Sloan/Jean intermodal transfer station are in the range of the threatened desert tortoise. The abundance of tortoises generally is moderate to high in Ivanpah Valley in relation to other areas in Nevada (Karl 1980, pages 75 to 87; BLM 1992, Map 3-13). This area is not critical habitat for desert tortoises (50 CFR 17.95).

One species classified by the Bureau of Land Management as sensitive, and by the State of Nevada as protected, occurs in the candidate Sloan/Jean station sites (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor* ssp. *roseus)* has been observed on the site southwest of Sloan and on the site east of Jean. There are no important game habitats (BLM 1998, Maps 2-1, 3-7, 3-8, and 3-9) and no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of these sites (TRW 1999k, page 3-36).

The only resident threatened or endangered species along the Sloan/Jean heavy-haul route is the desert tortoise. The entire route is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). The abundance of tortoises along the first part of the route in Ivanpah Valley is moderate to high in relation to other areas in Nevada (BLM 1992, Map 3-13). The abundance of tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low to very low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Four species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs in the Las Vegas Valley. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road in eastern Rock Valley on the Nevada Test Site, and the fringed myotis has been observed near the Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitats (BLM 1998, Maps 3-7 to 3-9) and there are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile).

Apex/Dry Lake Station and Route

The area that DOE is considering for the Apex/Dry Lake intermodal transfer station is northeast of Las Vegas in Dry Lake Valley. The Department is considering three sites in this area, two to the west of I-15 [0.18 and 3.6 square kilometers (45 and 890 acres)] and one east of the Interstate [0.95 square kilometer (240 acres)]. The elevation of these sites is about 610 meters (2,000 feet). This area is in the Mojave Desert and the predominant land cover type is creosote-bursage (100 percent). The associated route starts at the station area and crosses Las Vegas, Mercury, and Rock Valleys and Jackass Flats to Yucca Mountain at elevations ranging from 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along this route are creosote-bursage (77 percent) and Mojave mixed scrub (16 percent).

The only resident threatened or endangered species along the Apex/Dry lake heavy-haul route is the desert tortoise. The entire route passes through desert tortoise habitat (Bury and Germano 1994, pages 57 to 72), and the relative abundance of tortoises along this route through the Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low (BLM 1992, Map 3-13; Rautenstrauch and

O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Three species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road on the Nevada Test Site in eastern Rock Valley, and the fringed myotis has been observed near Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitat (BLM 1998, Maps 3-7 to 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of the intermodal transfer station area or the route.

3.2.2.2.5 *Cultural Resources*

The description of environmental conditions in this section focuses on archaeological and historic resources associated with the candidate intermodal transfer station areas and the associated heavy-haul routes. In addition, this section discusses Native American interests in relation to several of the heavy-haul truck routes. Unless otherwise noted, the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all) is the basis for the information in this section.

Archaeological and Historic Resources. Archaeological data from the candidate intermodal transfer station sites are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, four, seven, and two archaeological sites have been recorded at the Caliente, Sloan/Jean, and Apex/Dry Lake sites, respectively. These sites have not been evaluated with regard to their potential eligibility for listing in the *National Register of Historic Places.*

There is some relevant information about the candidate Caliente intermodal transfer location. Various cultural groups have occupied the Caliente/Meadow Valley Wash area for at least the past 11,000 years (Fowler et al. 1973, all; Fowler and Madsen 1986, all). Previously recorded prehistoric archaeological resources in the region include scattered lithic artifacts, rock shelters, temporary camps, and rock art (Kautz and Oothoudt 1992, all). Historic archaeological resources in the region typically consist of remains of late nineteenth- and early twentieth-century activities such as mining and ranching. The Caliente Railroad Depot is listed in the *National Register of Historic Places.*

In general, there are little or no current data for the presence of cultural resource sites in the existing road rights-of-way; with the exception of one route, field inventories have not been conducted. A few archaeological surveys have been conducted along or near the Caliente-Chalk Mountain heavy-haul route. An archival search of a 0.2-kilometer (0.1-mile)-wide corridor along this route identified five archaeological sites. Two of these sites are not considered eligible for inclusion on the National Register; the other three have not been evaluated.

Native American Interests. Section 3.2.2.1.5 discusses general Native American concerns about transportation routes.

The Moapa Paiute Indian Tribe is a Federally recognized tribe of about 290 Southern Paiute people. The tribe's reservation near the town of Moapa on I-15 and the Union Pacific Railroad's mainline contains homes and business enterprises. The reservation is about 6 kilometers (4 miles) east of the Caliente-Las

Vegas heavy-haul route and about 5 kilometers (3 miles) north of the Apex/Dry Lake station site (AIWS 1998, Chapter 4).

The Las Vegas Paiute Colony is a Federally recognized tribe of about 100 people living on two separate tribal parcels in southern Nevada (AIWS 1998, Chapter 4). One parcel near downtown Las Vegas consists of 73,000 square meters (18 acres) of land with 21 homes and various business enterprises. This parcel is about 11 kilometers (7 miles) from an overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes (northern Las Vegas beltway for the Las Vegas and Apex/Dry Lake routes, and western Las Vegas beltway for the Sloan/Jean route). The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16.2 square kilometers (4,000 acres) with 12 homes and various business enterprises. An overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes goes through a 1.6-kilometer (1-mile) corner of this parcel.

3.2.2.2.6 *Socioeconomics*

The candidate heavy-haul intermodal transfer station sites and routes would not appreciably affect counties other than those in which the facilities were located. Section 3.1.7 contains socioeconomic background information on the three counties (Clark, Lincoln, and Nye) most involved in the heavy-haul routes. The Caliente heavy-haul route is the only route involving a county outside the region of influence; it passes through Esmeralda County in addition to Lincoln and Nye Counties. Section 3.2.2.1.6 contains socioeconomic information for Esmeralda County.

3.2.2.2.7 *Noise*

Most of the proposed routes pass through unpopulated desert with background noise levels of 22 to 38 dBA. All routes pass through small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA (Table 3-30). Traffic noise along highways generally ranges from 5 to 15 dBA above natural background levels (EPA 1974, page D.5). Roadside noise levels are highly dependent on the volume of traffic, the road surface, composition of the traffic (trucks, automobiles, motorcycles, etc.), and vehicle speed. Measurements taken 90 meters (300 feet) from the centerline of U.S. 95 just outside the Nevada Test Site ranged from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Less traveled rural highways would have lower 1-hour noise levels, possibly as low as 33 dBA at 90 meters (300 feet) from the centerline. Communities potentially affected by the candidate intermodal transfer stations and associated heavy-haul routes were identified by examining the proposed route of each corridor and estimating if construction or heavy-haul vehicle noise could affect area communities. Occasional noise from passing military aircraft occurs near and in the Nellis Air Force Range.

Caliente Station

DOE is considering two parcels of land in Meadow Valley Wash several miles south of Caliente for the intermodal transfer station. A water treatment plant adjacent to the larger parcel could contribute to background noise levels. The other parcel of land has no buildings. Estimated noise levels range from 22 to 45 dBA depending on traffic volume (based on Table 3-30).

Caliente Route. The Caliente heavy-haul route goes from Caliente to the Yucca Mountain site, passing through or near the towns of Caliente, Tonopah, Goldfield, Beatty, Hiko, Rachel, Warm Springs, and Amargosa Valley. Estimated noise levels in these communities range from 40 to 55 dBA (based on Table 3-30). This longest route travels on existing highways through predominantly Bureau of Land Management land.

Caliente-Chalk Mountain Route. The Caliente-Chalk Mountain heavy-haul route would use existing paved roads to a point in western Lincoln County where it would turn south through the Nellis Air Force Range and the Nevada Test Site. Caliente and Rachel are the only towns through which the heavy-haul route would pass. Estimated noise levels in these communities would range from 45 to 55 dBA (based on Table 3-30).

Caliente-Las Vegas Route. The Caliente-Las Vegas heavy-haul route follows U.S. 93 from Caliente to I-15, then into Las Vegas primarily on Bureau of Land Management land. The section of the route on the planned Northern Beltway to U.S. 95 would have the highest noise levels, biased toward the 55-dBA level. Traffic noise levels along U.S. 95 would range from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Estimated noise levels in Caliente, Alamo, Indian Springs, and Mercury range from 40 to 55 dBA (based on Table 3-30).

Sloan/Jean Station

DOE is considering three parcels of land in the Sloan/Jean area. Some residences, a quarry, and a concrete plant are next to the northernmost site. The eastern parcel is along I-15 adjacent to several commercial enterprises. The third parcel is in the community of Jean and is close to two large casinos. Estimated noise levels in these areas, which are greater than levels encountered in unpopulated desert areas, range from 40 to 55 dBA (based on Table 3-30).

Sloan/Jean Route. The Sloan/Jean heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site, and would pass through a number of small towns and the western and northern portions of the Las Vegas Valley. Existing noise levels in the Las Vegas Valley probably range from 52 to 74 dBA; estimated noise levels in Indian Springs and Mercury range from 40 to 55 dBA (based on Table 3-30).

Apex/Dry Lake Station

The candidate location for the Apex/Dry Lake intermodal transfer station is in an unpopulated part of Dry Lake Valley. Existing noise levels are probably somewhat higher than typical levels for a desert environment because of vehicles that travel along I-15 in this area. Depending on local meteorological conditions, noise from the Apex industrial site and passing trains would add to the existing acoustic environment at this site. The northern boundary of one possible location for an intermodal transfer station in the Apex/Dry Lake area is about 3 kilometers (2 miles) south of the Moapa Indian Reservation.

Apex/Dry Lake Route. The Apex/Dry Lake heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site. It would pass through a number of small communities and the north end of the Las Vegas Valley. Existing noise levels in Indian Springs and Mercury probably range from 40 to 55 dBA (Table 3-30). Estimated noise levels in the Las Vegas Valley range from 52 to 74 dBA (based on Table 3-30).

3.2.2.2.8 *Aesthetics*

This section describes the existing aesthetic qualities associated with each of the intermodal transfer station sites and associated heavy-haul routes. Section 3.1.10 provides additional description of Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

Caliente Station

The proposed location for the Caliente facility is southeast of Caliente, on the western edge of Meadow Valley Wash. This area is in the Caliente Bureau of Land Management resource area and is classified Class III (Figure 3-26).

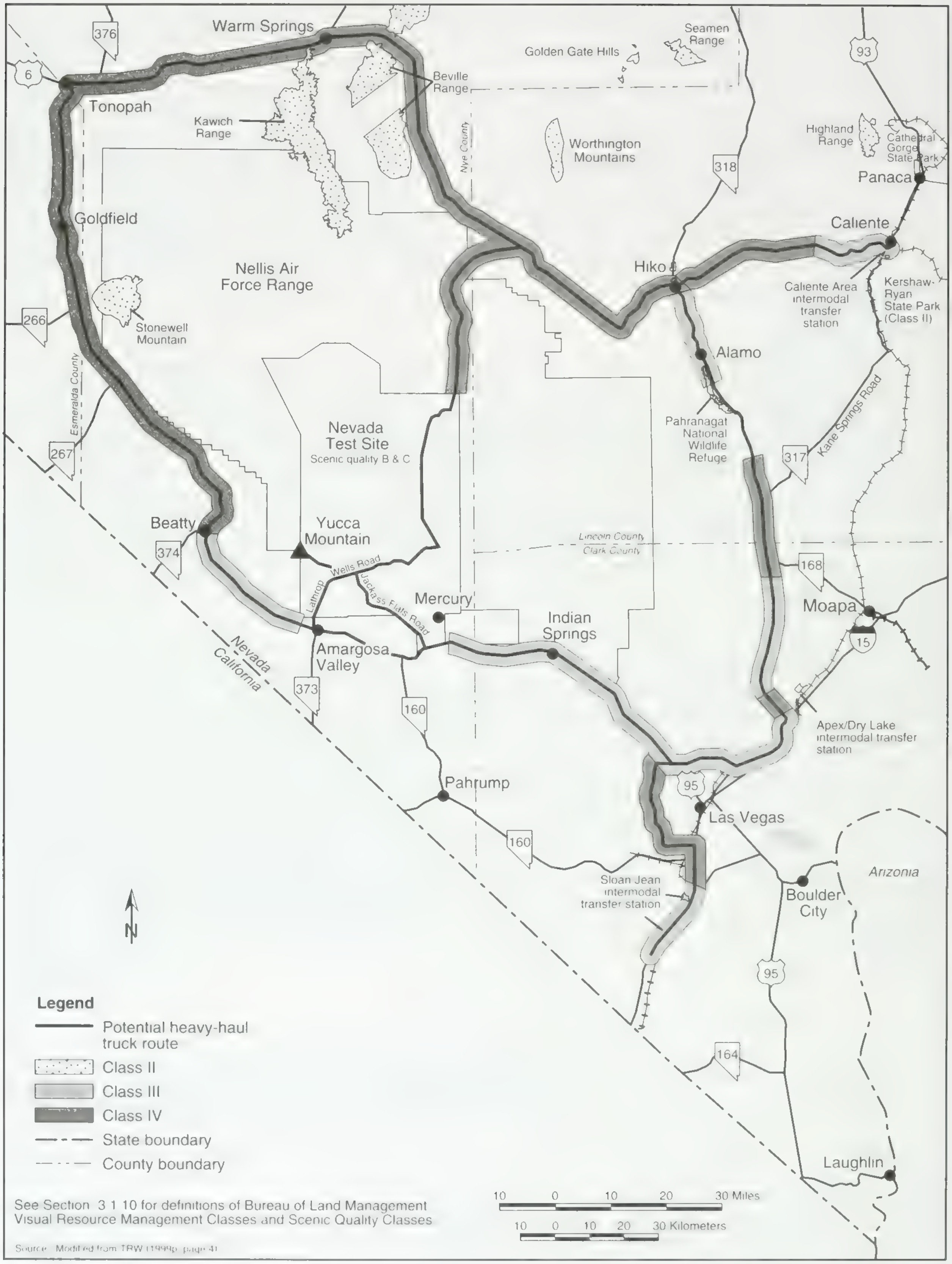


Figure 3-26. Visual Resource Management classes along the potential routes for heavy-haul trucks.

Caliente Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente route. The route passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. From Caliente to the south end of the Burnt Springs Range the route passes through Class III land, and then through Class IV land to Rachel. From Rachel to Tonopah the route crosses Class III land except portions of the Reveille and Kawich Ranges near Warm Springs, which are Class II areas. From Tonopah to Beatty, the route crosses Class IV land, then Class III land from Beatty to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or Class C (Figure 3-26).

Caliente-Chalk Mountain Route. Section 3.2.2.2.4 describes the environmental setting along the route. The route passes through the Caliente and Schell Bureau of Land Management resource areas. From Caliente to the south end of Burnt Springs Range, the route passes through Class III land. From the Burnt Springs Range west through Crystal Springs to Rachel, the route passes through Class IV land. The route from Rachel south crosses Class III and VI land to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

Caliente-Las Vegas Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente-Las Vegas route. The route passes through the Caliente, Schell, and Las Vegas Bureau of Land Management resource areas. From Caliente to Crystal Springs the route crosses Class III and Class IV land. From Crystal Springs south to the Pahranagat National Wildlife Refuge, the route crosses Class III land. The refuge is rated Class II. The route from the south end of the refuge to I-15 crosses Class III and IV land. The remainder of the route along I-15, the Northern Beltway, and U.S. 95 passes through Class III land. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

Sloan/Jean Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Sloan/Jean intermodal transfer station and associated route. The potential location for the Sloan/Jean intermodal transfer station has three parcels located some distance apart, two near Jean and one near Sloan. All portions of these parcels are in the Las Vegas Bureau of Land Management resource area and are designated as Class III lands. From Jean to Sloan the route travels through Class III lands. From Sloan along the Las Vegas Beltway to U.S. 95 is designated as Class IV lands. The portion of the route to the Nevada Test Site is through Class III lands. The remainder of the route on the Nevada Test Site is classified as scenic quality Class B and C (Figure 3-26).

Apex/Dry Lake Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Apex/Dry Lake intermodal transfer station and route. Most of the land in the potential intermodal transfer areas is classified as Class IV lands. A small portion of the southern section of land is designated as Class III lands. The entire route passes through Class III lands from the Apex/Dry Lake siding (and the location of the intermodal transfer station) to the Nevada Test Site boundary. On the Nevada Test Site the route to the repository passes through lands with a scenic quality designated as Class B and C (Figure 3-26).

3.2.2.2.9 *Utilities, Energy, and Materials*

The implementation of the heavy-haul approach for transporting spent nuclear fuel and high-level waste to the repository would involve the construction and operation of an intermodal transfer station and upgrades of existing highways. The scope of the utilities, energy, and materials analysis includes consumption of electric power, fossil fuel, and construction materials such as concrete and steel to support these activities. The sites studied for the intermodal transfer station (Caliente, Sloan/Jean, and Apex/Dry Lake) are in areas with at least some light industrial activity or other activity that requires electric power. The sites would, therefore, have access to light industrial levels of electric power. The

sites under consideration would also have access to the regional supply capability to provide fossil fuel and construction materials. Heavy-haul route upgrades would also use the southern Nevada regional supply system to provide materials for highway upgrades.

3.2.2.2.10 *Environmental Justice*

The candidate location for the Caliente intermodal transfer station is in Lincoln County and the associated heavy-haul routes go through Lincoln, Nye, and Esmeralda Counties for the Caliente route; Lincoln and Nye Counties for the Caliente-Chalk Mountain route; and Lincoln, Clark, and Nye Counties for the Caliente-Las Vegas route. Section 3.1.13 discusses minority and low-income populations in Clark, Lincoln, and Nye Counties; Section 3.2.2.1.10 discusses minority and low-income populations in Esmeralda County. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

The candidate locations for both the Sloan/Jean and Apex/Dry Lake intermodal transfer stations are in Clark County; the associated heavy-haul routes both go through Clark and Nye Counties. Section 3.1.13 discusses minority and low-income populations in Clark and Nye Counties.

None of the proposed intermodal transfer station sites is in a census block group with high minority or low-income populations, though a facility in the Caliente area would be near a block group with a low-income population and a facility in the Apex/Dry Lake area would be near the Moapa Indian Reservation, a block group with a high minority population.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the block groups are not near any of the possible sites for an intermodal transfer station. Tables 3-44 and 3-45 list by county the number of census block groups with high minority or low-income populations, respectively, near or through which the heavy-haul routes would pass. Table 3-46 lists the number of census block groups with high minority populations, high low-income populations, or both that each heavy-haul route could encounter.

Table 3-44. High minority population census block groups near or crossed by candidate routes for heavy-haul trucks.

County	Crosses	Near
Eureka	No route	No route
Lander	No route	No route
Nye	0	0
Esmeralda	0	0
Clark[a]	2	0
Lincoln	0	0

a. Outside Las Vegas.

Table 3-45. High low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

County	Crosses	Near
Eureka	No route	No route
Lander	No route	No route
Nye	2	1
Esmeralda	0	0
Clark[a]	0	0
Lincoln	1	0

a. Outside Las Vegas.

Table 3-46. High minority and high low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

Route	Minority	Low-income	Minority and low-income
Caliente	0	1[a]	0
Caliente-Chalk Mountain	0	0	0
Caliente-Las Vegas	2[b]	0	0
Apex/Dry Lake	2[b]	0	0
Sloan/Jean	1	0	0

a. Route passes near a low-income block groups in Nye County.
b. Route crosses two minority block groups in Clark County.

The transportation routes would not intersect any of the 90 block groups in the City of Las Vegas with low-income or minority populations or both.

3.2.2.2.11 *Existing Traffic on Candidate Routes for Heavy-Haul Trucks*

The description of the affected transportation environment characterizes routes in terms of traffic volume and roadway capability (DOE 1998m, pages 3-1 to 3-14). The potential for congestion and other problems on a roadway is expressed in terms of levels of service. The level of service scale ranges from A to F, as follows:

A Indicates free-flow conditions.

B Indicates free-flow, but the presence of other vehicles begins to be noticeable. Average travel speeds are somewhat lower than level of service A.

C Indicates a range in which the influence of traffic density on flow becomes marked. The ability to maneuver in the traffic stream and to select an operating speed is clearly affected by the presence of other vehicles.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-47 lists current levels of service on potential heavy-haul routes (excluding the planned Las Vegas Beltway).

Table 3-47. Existing levels of service along candidate routes for heavy-haul trucks.[a]

Route segment	Level of service
Caliente	
U.S. 93 to U.S. 6/U.S. 95 interchange	A
U.S. 95/U.S. 6 to Tonopah city limit	C
U.S. 95 (to Mercury, Nevada)	B
Caliente-Chalk Mountain	
Caliente to Rachel	A
Cost of route on U.S. Government facility	N/A
Caliente-Las Vegas	
U.S. 93 (between I-15 and Caliente)	A
I-15 (to Craig interchange)	A
I-15 (in Las Vegas)	E or F[b]
U.S. 95 (in Las Vegas)	E or F[b]
U.S. 95 (Las Vegas to Mercury)	B
Sloan/Jean	
I-15 (to and in Las Vegas)	C, F[b]
U.S. 95 (in Las Vegas)	C, F[b]
U.S. 95 (Las Vegas to Mercury)	B
Apex/Dry Lake	
I-15 (to Craig interchange	A
I-15 (in Las Vegas)	E and F[b]
U.S. 95 (in Las Vegas)	E and F[b]
U.S. 95 (Las Vegas to Mercury)	B

a. Source: DOE (1998m, pages 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

3.3 Affected Environment at Commercial and DOE Sites

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear

fuel and high- level radioactive waste would remain at commercial and DOE sites throughout the United States. For this alternative, this section describes the affected environment that reflect the average or mean conditions of the sites. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data from actual sites to develop the hypothetical sites.

To develop the hypothetical sites (see Appendix K for more information), DOE divided the 77 sites among five regions (Figure 3-27). Climate varies considerably across the United States. The radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed these release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

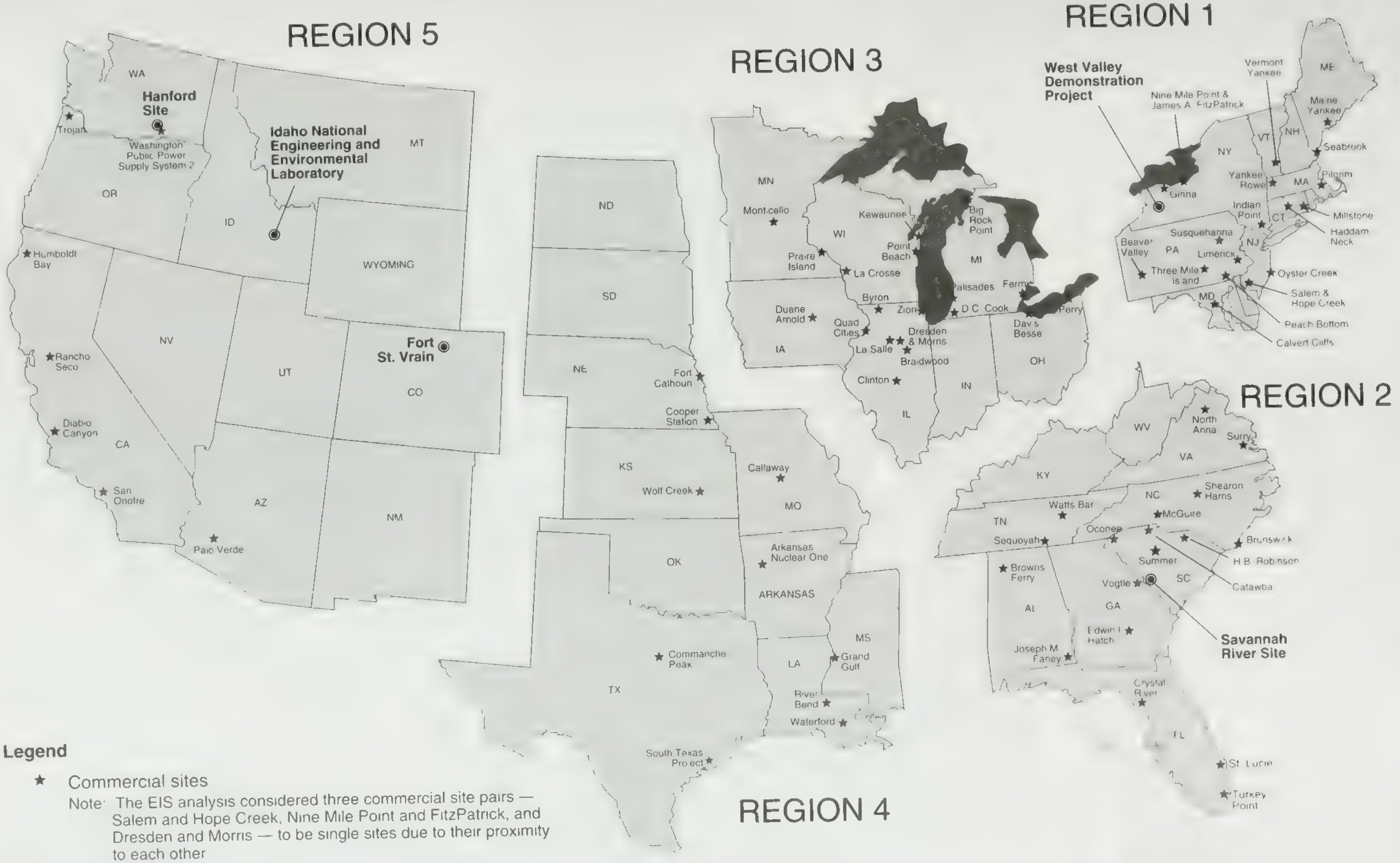
3.3.1 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)
- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)
- Temperature
- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-48 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.



Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other

◉ DOE sites

Note. The EIS analysis included the high-level radioactive waste and spent nuclear fuel at West Valley. The State of New Yorkowns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste off the West Valley site. DOE owns and is responsible for the spent nuclear fuel at the site.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Figure 3-27. Commerical and DOE sites in each No-Action Alternative analysis region.

Table 3-48. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)[a]	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weight percent)	Average temperature (°C)[b]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

3.3.2 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-49 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

Table 3-49. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0[b] - 100	0.7 - 4.4	0.4 - 2,100	0.3 - 56	10 - 5,000	10 - 6,000
2	10 - 250	0.6 - 10	35 - 5,000	3.3 - 250	11 - 310,000	460 - 310,000
3	10 - 250	0.5 - 14	32 - 1,500	1.3 - 410	9 - 44,000	65 - 45,000
4	10 - 100	0.2 - 7.1	110 - 2,300	3.9 - 960	300 - 520,000	460 - 520,000
5	0 - 10	0.9 - 73	14 - 4,700	1.7 - 170	0 - 25,000	200 - 26,000

a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there was no soil at the site.

3.3.3 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-28) and the number of public drinking water systems that draw water from the potentially contaminated waterways (Table 3-50). DOE calculated the river flow past each population center (Section 3.3.4) along each river, and used this number in the calculation to determine dose to the population.

Table 3-50. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	**486**	**31,000,000**

a. Sources: Based on current information and the 1990 census.

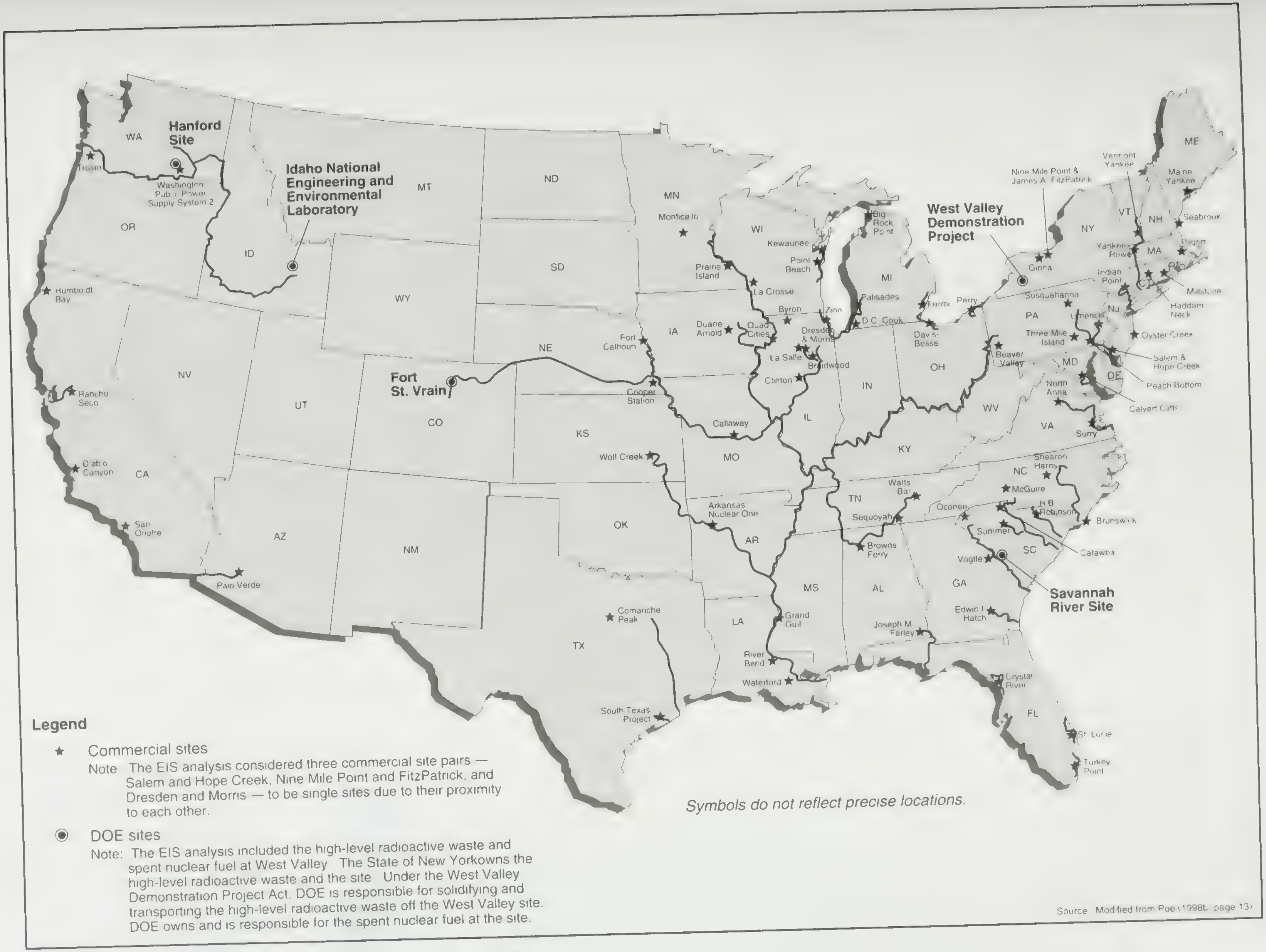


Figure 3-28. Major waterways near commercial and DOE sites.

3.3.4 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-50 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

4

Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure

4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period up to and during the completion of repository closure. For purposes of analysis, the duration that the repository would remain open varied between 50, 100, and 300 years after receipt of the first spent nuclear fuel or high-level radioactive waste shipment. Chapters 5 and 6 discuss the environmental consequences of long-term repository performance and transportation, respectively. Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of disposal containers and shipping casks, and a floodplain assessment. The implementation of the Proposed Action could require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

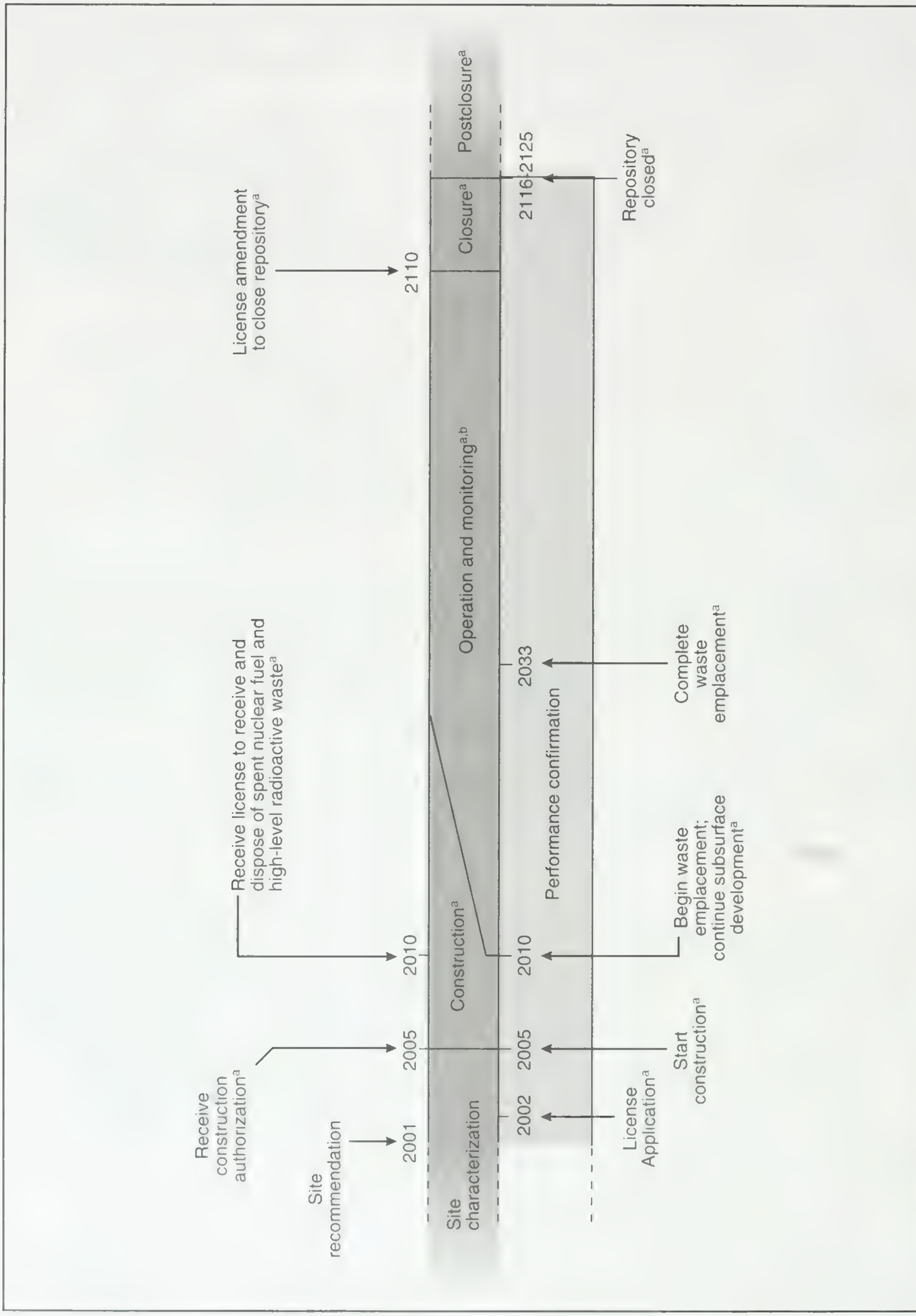
The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository. In addition, DOE analyzed packaging and thermal load scenarios to cover a reasonable range of possible impacts.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the analytic scenarios evaluated in this environmental impact statement (EIS). Chapter 2 describes these scenarios in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION PERFORMANCE CONFIRMATION ACTIVITIES (2001 TO 2005)

The performance confirmation program would continue the current site characterization activities—tests, experiments, and analyses—for as long as required. DOE would continue these activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to



a. If Yucca Mountain is approved.
b. The EIS analysis assumed that waste emplacement would occur over a 24-year period ending in 2033.

Source: Modified from TRW (1999b, Figure 1.5.1, page 1.3).

Figure 4-1. Expected monitored geologic repository milestones.

determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.

INITIAL CONSTRUCTION ACTIVITIES (2005 TO 2010)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. Assuming this authorization, construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Initial subsurface construction would prepare the first emplacement drifts for the start of emplacement activities in 2010. As mentioned above, performance confirmation activities would be ongoing during this period.

CONTINUING CONSTRUCTION ACTIVITIES AND REPOSITORY OPERATION AND MONITORING (2010 TO 2110)

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. Assuming DOE received the license, emplacement of these materials in the repository would be likely to begin in 2010 and end in 2033. The development (construction) of the subsurface would continue during waste emplacement, and would end in about 2031 for the high or intermediate thermal load scenario or about 2032 for the low thermal load scenario.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary.

Monitoring activities would begin with the emplacement of the first waste package in 2010 and would last between 50 and 300 years. Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. To ensure flexibility for future decisionmakers, DOE is designing the repository with the capability for closure as early as 50 years after the start (26 years after the completion) of waste emplacement or as late as 300 years after the start (276 years after the completion) of emplacement. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for as long as 300 years after the start of emplacement. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement, but also assesses impacts for closure starting 50 and 300 years after the start of emplacement.

As mentioned above, DOE would continue its performance confirmation activities during the construction, waste emplacement, and monitoring activities.

CLOSURE PHASE (2110 TO 2116 OR 2125)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take from 6 to 15 years, depending on the thermal load scenario. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Potentially backfilling the main drifts, access ramps, ventilation shafts, and connecting openings

- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY ANALYTIC SCENARIOS

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a set of repository design scenarios (thermal loads) for evaluation in this EIS. Because it cannot predict the specific transportation option or mode (truck or rail) or the packaging option (canistered or uncanistered) for each shipment of spent nuclear fuel and high-level radioactive waste to the proposed repository, DOE has also identified a set of transportation and packaging scenarios for evaluation. Whether canistered or uncanistered, each shipment of spent nuclear fuel and high-level radioactive waste would be in a Nuclear Regulatory Commission-certified shipping cask.

DOE is considering three thermal load scenarios to represent the potential thermal loads that could be part of a license application to the Nuclear Regulatory Commission. These scenarios include a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load), a relatively low emplacement density (low thermal load), and an emplacement density between the high and low thermal loads (intermediate thermal load). The emplacement density of spent nuclear fuel and high-level radioactive waste in the repository is referred to as the *areal mass loading* (the amount of material in a given area). The spacing of the emplacement drifts and the waste packages in those drifts would control the thermal load of the repository. The additional spacing required for lower thermal loads would increase the amount of subsurface area needed and, therefore, would require more excavation.

Because the specific mix of canistered and uncanistered spent nuclear fuel that would arrive at the repository is not known at this time, this EIS analyzes the following packaging scenarios to address the potential range of environmental impacts from surface facility operations:

- A mostly legal-weight truck, uncanistered commercial fuel receipt scenario (uncanistered scenario)
- A mostly rail, canistered commercial fuel receipt scenario (canistered scenario) that includes:
  - A disposable canister scenario
  - A dual-purpose canister scenario

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Performance Confirmation and from Land Withdrawal

Performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (4,900 acres), current right-of-way reservations N-47748 [210 square kilometers (52,000 acres)] and N-48602 [about 75 square kilometers (19,000 acres)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1).

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 3.5 square kilometers (870 acres) composed of small noncontiguous areas in the larger 600-square-kilometer (150,000-acre) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little between the thermal load and packaging scenarios. Most of the surface facilities and disturbed land would be in the North and South Portal Operations Areas. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with

uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would recontour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from performance confirmation, construction, operation and monitoring, and closure. Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling, nitrogen dioxide, sulfur dioxide, and particulate matter emissions from fossil fuel consumption, and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not consider the two other criteria pollutants, lead and ozone. There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a qualitative comparison to the new National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$). A Federal appeals court recently struck down the Environmental Protection Agency's new national ambient air quality standards for particulate matter (American Trucking v. EPA 1999, all). The Environmental Protection Agency has announced that it will appeal the decision. The EIS used these standards, among other air quality standards that were not at issue in that case, in analyzing the air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from NCRP (1996, Volume 1, pages 113 and 125) and ICRP (1994, page 24) to estimate doses to noninvolved workers (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases. Appendix G provides more details on the methods used for air quality analysis.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. Appendix G describes the methods, procedures, and basis of the analysis.

4.1.2.1 Impacts to Air Quality from Performance Confirmation (2001 to 2005)

Performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, nitrogen oxides, sulfur oxides, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, ozone). This analysis assumed that site characterization activities are representative of performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction (2005 to 2010)

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust (South Portal). The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the South Portal Operations Area
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all cases except one: the 24-hour PM_{10} concentrations for the three thermal load scenarios would be about 4 percent of the

Table 4-1. Estimated maximum construction phase concentrations of criteria pollutants and cristobalite at the analyzed land withdrawal area boundary (micrograms per cubic meter).[a]

			Thermal load					
			Maximum concentration[c]			Percent of regulatory limit		
Pollutant	Averaging time	Regulatory limit[b]	High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.36	0.36	0.39	0.36	0.36	0.39
Sulfur dioxide	Annual	80	0.088	0.088	0.091	0.11	0.11	0.12
	24-hour	365	1.0	1.0	1.0	0.28	0.28	0.29
	3-hour	1,300	6.3	6.3	6.5	0.49	0.49	0.50
Carbon monoxide	8-hour	10,000	3.8	3.8	4.1	0.037	0.037	0.040
	1-hour	40,000	23	23	25	0.058	0.058	0.062
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.66	0.70	0.65	1.3	1.4	1.3
	24-hour	150 (65)	6.1	6.4	6.0	4.0	4.3	4.0
Cristobalite	[Annual[d]]	[10[d]]	0.022	0.026	0.011	0.22	0.26	0.11

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be somewhat higher under the low thermal load scenario during the construction phase because of higher consumption of diesel fuel and resultant vehicle emissions around the South Portal Operations Area. The additional consumption and emissions would be related mainly to the preparation and maintenance of the excavated rock pile. Under this scenario, the rock pile would be about 5 kilometers (3 miles) east of the South Portal Operations Area, rather than in that operations area as it would be for the high and intermediate thermal load scenarios. Because the pile would be away from the South Portal Operations Area, it would not be subject to the operations area height restrictions. DOE could make a higher pile, reducing the area that would be disturbed and creating a more favorable surface-to-volume ratio for limiting fugitive dust emissions. This pile location would also be 5 kilometers farther from the location of the maximally exposed individual, which would result in lower PM_{10} concentrations. The PM_{10} contribution from surface disturbance activities would be about the same for the three thermal load scenarios. Overall, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, page 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline

silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles will rapidly deposit on the surface (EPA 1996a, page 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.025 microgram per cubic meter or less for the thermal load scenarios. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, from which it would be exhausted as part of repository ventilation. The analysis based potential releases of radon-222 on observed concentrations of the gas in the Exploratory Studies Facility during working hours when the ventilation system was operating. The concentrations ranged from 0.65 to 163 picocuries per liter, with a median concentration of 24 picocuries per liter. Total estimated radon releases of 1,500, 1,600, or 1,600 curies would occur during the construction phase for the high, intermediate, or low thermal load scenario, respectively. These releases, and the potential doses that resulted from them, would be similar because the excavated volume of the repository and the repository flowrate would be similar under each scenario. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be no more than 2.1, 2.5, or 2.5 millirem for the 5-year initial construction period under the high, intermediate, or low thermal load scenario, respectively. As a point of reference, the annual dose to the offsite maximally exposed individual would be about 5 percent of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to releases of radon. The

offsite population dose would be 11, 13, or 13 person-rem, respectively. The median dose to the maximally exposed noninvolved repository worker would range from 4.7 to 5.4 millirem annually during the initial construction period for the three thermal load scenarios. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all of the repository workers on the surface. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air pathway would not exceed 10 person-rem for any thermal load scenario (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and initial construction period doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during initial construction period.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	2.1	0.43	2.5	0.49	2.5	0.49
80-kilometer population[d] (person-rem)	11	2.3	13	2.6	13	2.6
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	23	4.7	27	5.4	27	5.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)	9.0[f]	1.8[f]	10[f]	2.0[f]	10[f]	2.0[f]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.012	0.0025	0.014	0.0028	0.014	0.0028

a. Numbers are rounded to two significant figures.
b. These releases were estimated using the average repository volume during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Operations Area.
f. Values are for the uncanistered packaging scenario. The dual-purpose and disposable canister packaging scenario values would be somewhat lower, due to differences in the number of surface facility construction workers.
g. The analysis included noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Continuing Construction, and Operation and Monitoring (2010 to 2110)

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository, which would last from 2010 to 2110. Activities during this phase would include the continued excavation of subsurface drifts (2010 to 2033), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (2010 to 2033), the emplacement of disposal containers in the repository (2010 to 2033), and the continued monitoring of the disposal containers and maintenance of repository facilities (2034 to 2110).

4.1.2.3.1 Nonradiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring

DOE evaluated nonradiological air quality impacts from activities from 2010 to 2033, when handling and continued subsurface development and emplacement activities would occur simultaneously. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the placement and maintenance of excavated rock at a surface storage pile
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation
- Gaseous criteria pollutants and particulate matter from oil-fed boilers at the North and South Portal Operations Areas
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the thermal load and packaging scenarios. The lower thermal loads would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance. The uncanistered packaging scenario would require larger facilities at the North Portal Operations Area, which would necessitate a larger boiler for heating.

Table 4-3 lists estimated maximum concentrations at the analyzed land withdrawal area boundary for the high, intermediate, and low thermal load scenarios. These impacts are based on surface facilities built for the uncanistered packaging scenario. Other packaging scenarios would have similar or slightly smaller impacts because they would require smaller boilers.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For all three thermal load scenarios, the public maximally exposed individual would receive no more than 1 percent of the applicable regulatory limits, with one exception: the 24-hour PM_{10} value would be about 2 percent. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the analyzed land withdrawal area boundary. As discussed for the initial construction period (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The estimated exposures to cristobalite from repository operations would be small, about 0.015 microgram per cubic meter or less for all three thermal load scenarios.

Table 4-3. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary from emplacement, receipt and packaging, and development activities (2010 to 2033) during the operation and monitoring phase (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c]			Percent of regulatory limit		
			High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.45	0.45	0.82	0.46	0.46	0.83
Sulfur dioxide	Annual	80	0.14	0.14	0.16	0.18	0.18	0.23
	24-hour	365	1.8	1.8	2.1	0.50	0.50	0.57
	3-hour	1,300	11	11	13	0.87	0.87	1.0
Carbon monoxide	8-hour	10,000	4.2	4.2	7.3	0.041	0.041	0.072
	1-hour	40,000	28	28	46	0.070	0.070	0.11
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.22	0.22	0.27	0.43	0.44	0.54
	24-hour	150 (65)	3.0	3.1	3.4	2.0	2.1	2.3
Cristobalite	[Annual[d]]	[10[d]]	0.0097	0.012	0.015	0.097	0.12	0.15

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be somewhat higher during construction because of the higher rate of excavation. Concentrations of gaseous criteria pollutants would increase during emplacement and development activities because two boilers rather than one would be operating, even though vehicle emissions would decrease during emplacement and development. The exception would be emissions of carbon monoxide, which would be related more to vehicle emissions than boiler emissions. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities (from 2034 to 2110) at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the analyzed land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

4.1.2.3.2 *Radiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase (2010 to 2033). Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities (2034 to 2110). During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Handling, Emplacement, and Continuing Development Activities (2010 to 2033). The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (NRC 1979, page 4-10). From 90 to 2,600 curies would be released annually, depending on the packaging scenario (TRW 1999a, page 75). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 1.4×10^{-2} curie of radon-220, 4.6×10^{-6} curie of radon-222, and very small quantities of xenon-127 (TRW 1999a, page 75). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger excavated volume, with more radon emanations from the repository walls and greater quantities exhausted by ventilation. The estimated differences in radon releases between the thermal load scenarios would be a function of the excavated repository volume, the exhaust ventilation flowrate, and the repository air exchange rate; the packaging scenario would not affect radon releases. The low thermal load scenario would have the largest excavated volume, largest exhaust flowrates and, therefore, the largest radon release. Appendix G, Section G.2, contains more information on repository volume, flowrates, and radon releases for the three thermal load scenarios.

Table 4-4 lists estimated annual doses and doses from 24 years of emplacement activities to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. Appendix G, Section G.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be small contributors to the overall public dose in comparison to radon-222 decay products from the subsurface facilities. All the radionuclides released from the surface facilities would be very small contributors to the overall public dose with the largest, krypton-85, contributing less than 0.001 percent of the dose to the public and noninvolved workers.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 19, 22, or 44 millirem for the 24 years of emplacement and development activities under the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 8, 9, or 18 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to radon releases. The population dose would be 99, 120, or 230 person-rem, respectively. The dose to members of the public would vary by thermal load scenario but not by packaging scenario because naturally occurring radon-222 released from the subsurface would be the dominant dose contributor. Releases from surface facilities during spent nuclear fuel handling would make very small differences in the dose received.

The median dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 82 millirem for 24 years of emplacement activities.

Table 4-4. Estimated radiation doses for maximally exposed individuals and populations during handling, emplacement, and development activities during operation and monitoring phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual average[c]	Total	Annual average	Total	Annual average
Dose to public						
Offsite MEI[d] (millirem)	19	0.78	22	0.93	44	1.8
80-kilometer population[e] (person-rem)	99	4.1	120	4.9	230	10
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[f] (millirem)	82	3.4	82	3.4	82	3.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)						
Uncanistered scenario	63	2.6	75	3.1	140	5.7
Disposable canister scenario	62	2.6	74	3.1	130	5.6
Dual-purpose canister scenario	62	2.6	74	3.1	130	5.6
Nevada Test Site noninvolved worker population[h] (person-rem)	0.12	0.005	0.14	0.0059	0.27	0.012

a. Numbers are rounded to two significant figures.
b. Emplacement activities during the operation and monitoring phase would last 24 years, from 2010 to 2033. Continued subsurface development activities would last 22 years.
c. Annual average values reflect the increasing repository volume and radon release during subsurface development.
d. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository.
e. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Operations Area.
g. The analysis considered noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

regardless of the thermal load scenario. The doses would be constant across the thermal load scenarios because the volume of the development area ventilated in each scenario would be similar. The estimated number of noninvolved workers at the repository site, whom the analysis assumed would all be at the North Portal Operations Area, would vary among the packaging scenarios. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers for the uncanistered packaging scenario and about 1,000 workers for the disposable canister and dual-purpose canister packaging scenarios. There would be an estimated 70 additional workers at the South Portal Operations Area regardless of packaging scenario. The combination of the low thermal load scenario (which would have the largest radon release) and the uncanistered packaging scenario would result in the highest noninvolved worker population dose, 140 person-rem over the 24-year emplacement period. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring and Maintenance Activities (2034 to 2110). Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would have minimal potential impact on air quality during monitoring and maintenance activities, except there would be a larger population of noninvolved workers employed for decontamination and these workers would be exposed to naturally occurring radon ventilated from the

subsurface. The potential for releases of radionuclides from the surface facilities during these activities would be minimal and impacts would be very small.

Table 4-5 lists estimated annual doses and total doses that would occur over the 76 years of monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 30, 36, or 88 millirem during monitoring and maintenance activities of the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 13 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit would not apply to repository radon releases. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

Table 4-5. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from subsurface monitoring and maintenance activities (including decontamination) during operation and monitoring phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	30	0.43	36	0.51	88	1.3
80-kilometer population[d] (person-rem)	160	2.1	190	2.5	470	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	2.0	0.039	2.3	0.046	5.8	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.14	0.025, 0.00087[f]	0.16	0.029, 0.0010[f]	0.40	0.072, 0.0026[f]
Disposable canister scenario	0.12	0.018, 0.00087[f]	0.14	0.021, 0.0010[f]	0.34	0.052, 0.0026[f]
Dual-purpose canister scenario	0.12	0.019, 0.00087[f]	0.14	0.022, 0.0010[f]	0.35	0.055, 0.0026[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.27	0.0035	0.32	0.0042	0.79	0.010

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of the 76 years of monitoring and maintenance activities, which would last until 2110.
c. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository. Values are for a 70-year lifetime.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area. Values are for a 50-year onsite working lifetime.
f. First value is for the 3 years of decontamination activities; second value is for the 73 years of monitoring and maintenance.
g. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The population dose for 76 years of monitoring and maintenance activities would be 160, 190, or 470 person-rem, respectively. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal, would be 2.0, 2.3, or 5.8 millirem for a 50-year working lifetime during monitoring and maintenance activities for the high, intermediate, or low thermal load scenario, respectively. The dose over 76 years to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would

vary depending on the thermal load scenario and the packaging scenario. The combination of the low thermal load scenario (largest radon release) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest noninvolved (surface) worker population dose, 0.40 person-rem for the 76-year monitoring and maintenance period. The extension of monitoring and maintenance activities to 276 years would extend these impacts to future generations of workers and the public. Section 4.1.7 discusses impacts to workers directly involved in monitoring and maintenance activities.

4.1.2.4 Impacts to Air Quality from Closure (2110 to 2125)

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing (in a backfill preparation plant), and transfer of excavated rock to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from fuel consumption
- Particulate matter from a concrete batch plant
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land
- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the high, intermediate, and low thermal load scenarios.

Gaseous criteria pollutants would result primarily from vehicle exhaust. The low thermal load scenario would have somewhat higher emissions because of a larger vehicle fleet. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 5 percent of the regulatory limit for all three thermal load scenarios. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the muck pile would be cristobalite. Table 4-6 lists

Table 4-6. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Maximum concentration[c]			Percent of regulatory limit		
			Thermal load			Thermal load		
Pollutant	Averaging time	Regulatory limit[b]	High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.080	0.13	0.12	0.080	0.13	0.12
Sulfur dioxide	Annual	80	0.0076	0.013	0.011	0.097	0.016	0.014
	24-hour	365	0.57	0.093	0.082	0.016	0.025	0.022
	3-hour	1,300	0.045	0.74	0.66	0.035	0.057	0.050
Carbon monoxide	8-hour	10,000	0.67	1.1	0.98	0.0065	0.011	0.0095
	1-hour	40,000	4.1	6.6	5.9	0.010	0.017	0.015
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.52	0.56	0.53	1.0	1.1	1.1
	24-hour	150 (65)	6.5	6.8	6.6	4.3	4.5	4.4
Cristobalite	[Annual[d]]	[10[d]]	0.010	0.014	0.0053	0.10	0.14	0.053

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.014 microgram per cubic meter or less for all three thermal load scenarios. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between any of the scenarios.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Exposure to the noninvolved (surface) worker population and the public would occur during the 6-year period while this group was working on surface facility closure. For the low thermal load scenario, exposures to members of the public and noninvolved workers would occur during a 15-year period.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual about 20 kilometers (12 miles) south of the repository would be 2.6, 3.0, or 19 millirem for the 6, 6, or 15 years of closure activities under the high, intermediate, or low thermal load scenario, respectively. Although the limit does not apply to releases of radon, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 12 percent, respectively, of the 10 millirem-per-year regulatory limit (40 CFR Part 61). The population dose would be 13, 15, or 93 person-rem, respectively, for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.24, 0.28, or 1.7 millirem, respectively, for

Table 4-7. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Release	Total	Annual	Total	Annual	Total	Annual
Dose to public						
MEI[c] (millirem)	2.6	0.43	3.0	0.50	19	1.2
80-kilometer population[d] (person-rem)	13	2.1	15	2.5	93	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	0.24	0.039	0.28	0.046	1.7	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.041	0.0068	0.048	0.0080	0.12	0.020
Disposable canister scenario	0.029	0.0049	0.035	0.0058	0.086	0.014
Dual-purpose canister scenario	0.032	0.0053	0.037	0.0062	0.093	0.016
Nevada Test Site noninvolved worker population[f] (person-rem)	0.021	0.0035	0.025	0.0042	0.16	0.010

a. Numbers are rounded to two significant figures.
b. The closure phase would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

the entire closure phase. The dose to the noninvolved repository (surface) worker population would vary depending on the thermal load and packaging scenarios. The combination of the low thermal load scenario (largest radon releases) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest total noninvolved worker population dose, 0.12 person-rem.

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of

groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.

- Water demand under scenarios with the highest consumption would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. However, the highest demand scenario in combination with ongoing Nevada Test Site demand from the same basin would exceed the lowest estimates of perennial yield.

- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Desert in comparison to the quantities of water already being withdrawn there.

- The potential for flooding at the repository site is extremely small.

4.1.3.1 Impacts to Hydrology from Performance Confirmation

Performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-15). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial

yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River underground. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction period (2005 to 2010), and during the emplacement and development activities of the continuing construction, operation, and monitoring period that would follow (2010 to 2033), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DOE 1997i, pages 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization did not cause water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (Flint, Hevesi, and Flint 1996, pages 57 to 59), when combined with application rates measured during site characterization, show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operation and monitoring phase while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Operations Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-8 lists discharge estimates to the South Portal

Table 4-8. Annual water discharges to South Portal evaporation pond for thermal load scenarios.[a,b]

Phase	High thermal load	Intermediate thermal load	Low thermal load
Construction			
Discharge (cubic meters)[c]	8,400	10,000	10,000
Duration (years)	5	5	5
Operation and monitoring			
Discharge (cubic meters)	7,900	9,500	33,000
Duration (years)	22	22	22

a. Source: TRW (1999b, pages 6-9 and 6-18).

b. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.

c. To convert cubic meters to gallons, multiply by 264.18.

evaporation pond for the three thermal load scenarios. During the operation and monitoring phase, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. DOE would also investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. Water collected from the emplacement side of the subsurface area, if any, would also be pumped to this pond after verification that it was not contaminated. Table 4-9 lists discharge estimates to the North Portal evaporation pond for each packaging scenario during the operation and monitoring phase.

Table 4-9. Annual water discharges to North Portal evaporation pond during operation and monitoring phase for each packaging scenario.[a]

	Packaging scenario[b]		
Factor	UC	DISP	DPC
Discharge (million liters)[c]	30	25	25
Duration (years)	24	24	24

a. Source: TRW (1999a, page 75).

b. UC - uncanistered; DISP disposable canister; DPC dual-purpose canister.

c. To convert liters to gallons, multiply by 0.26418.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (TRW 1998f, page 16). The North Portal evaporation pond, which is intended primarily for cooling and heating process water, would, at a minimum, have a polyvinyl chloride liner (TRW 1998f, pages 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. Section 4.1.4.2 discusses impacts to wildlife that could result from the presence of these ponds. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Other uses of water during the continuing construction, operation, and monitoring period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface from monitoring and maintenance activities and from closure would be similar to or less than those discussed for the initial construction period and emplacement and development activities. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A, *General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Restricted Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Restricted Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (TRW 1998f, pages 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. However, the inundation levels expected from a 100-year, 500-year, or regional maximum flood would represent little hazard to the proposed repository, the portals of which would be at higher elevations than the flood-prone areas (TRW 1999h, page 2-7).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a spill prevention, control, and countermeasures plan [Kiewit (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Restricted Area and one for the balance-of-plant facilities. The basin for the Restricted Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Both the South and North Portal Operations Areas would contain fuel-oil storage tanks. These tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [about 480 to 1,300 liters (130 to 330 gallons) a year] (TRW 1999a, page 74). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Restricted Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the continuing construction, operation, and monitoring period would be managed in the Restricted Area of the North Portal Operations Area. This would include the

Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components.

During the continuing construction, operation, and monitoring period a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DOE 1998a, Volume 2, page 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2 square kilometers (500 acres) of land would be disturbed during the construction and operation and monitoring phases (see Chapter 2). Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, one side of the proposed North Portal facilities is drained by Midway Valley Wash and the other is drained by Drill Hole Wash. The 0.6 square kilometer (150 acres) of disturbance at the North Portal area (of the total 2 square kilometers disturbed) would be small (less than 4 percent) in comparison to the estimated 18 square kilometers (4,400 acres) that comprise the drainage area for the Midway Valley and Drill Hole Washes by the time they reach the North Portal area (Bullard 1992, Table 5).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation

efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

If DOE received authorization to construct, operate and monitor, and close a geologic repository at Yucca Mountain, it would ship spent nuclear fuel and high-level radioactive waste to the repository for a period of about 24 years beginning in 2010. Some transportation-related construction, operation, and maintenance actions associated with the DOE proposal would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Other construction, operation, and maintenance actions could occur in floodplains or wetlands elsewhere in Nevada along one of five alternative rail corridors DOE could select to transport spent nuclear fuel and high-level radioactive waste to the repository. Construction, operation, and maintenance actions could also occur in floodplains or wetlands at one of three alternative intermodal transfer station sites in Nevada if DOE chose a heavy-haul truck route for transportation.

Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity. The assessment analyzed the potential effects of these actions on the floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain.

The assessment in Appendix L presents a programmatic comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites. In general, wetlands have not been delineated along the rail routes or at the three station sites. If DOE selected a rail corridor or heavy-haul truck route to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would prepare a detailed floodplain/wetlands assessment of the selected alternative.

Repository-related structures could affect small drainage channels or washes. DOE expects to address these other washes with minor diversion channels, culverts, or similar drainage control techniques.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the relatively short duration of the active life of the repository, which would include construction, operation and monitoring, and closure. The following impacts would be of primary concern during the active life of the repository:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer

- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository

- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff

(as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (TRW 1999h, pages 2-19 to 2-21), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the North and South Portal Operations Areas, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DOE 1997j, all). This careful use of water in the subsurface would continue during repository construction activities. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be small and of minimal consequence to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill

Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction period and the continuing construction, operation, and monitoring period. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-10 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the thermal load scenario because the emplacement of less spent nuclear fuel (that is, low thermal load) per foot of repository tunnel would require more excavation. Water demand during these phases would also depend on the packaging scenario.

Table 4-10. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Proposed schedule	Water demand (acre-feet)[b] by thermal load		
		High	Intermediate	Low
Construction	2005 - 2010	150[c]	170[c]	170[c]
Operation and monitoring (by packaging scenario)				
Emplacement and development activities[d]	2010 - 2033			
Uncanistered		250	260	480
Disposable canister		220	230	450
Dual-purpose canister		220	230	450
Monitoring activities[e]	2033 - 2036			
Uncanistered		200	200	200
Disposable canister		160	160	160
Dual-purpose canister		160	160	160
Closure	2110 to varies			
Each packaging scenario		80	90	90

a. Source: TRW (1999a, pages 71, 74, 78, and 81); TRW (1999b, pages 6-3, 6-14, 6-21, 6-27, 6-28, and 6-37).
b. To convert acre-feet to cubic meters, multiply by 1,233.49.
c. Does not include water needed to construct a potential rail line.
d. Construction (or development) of the subsurface area during the operation and monitoring phase would take 22 years for the Proposed Action (emplacement would continue another 2 years). The values shown represent the highest demands projected for this phase and would occur during the period when both subsurface development and nuclear material emplacement were underway.
e. Values shown for monitoring activities are only applicable to the first 3 years (as shown by the schedule), when decontamination of surface facilities would be performed. Water demand for the 73 years that follow would be minimal.

As listed in Table 4-10, water demand during initial construction would range from about 0.19 million to about 0.21 million cubic meters (150 to 170 acre-feet) per year, depending on the thermal load scenario. Further, depending on the thermal load and packaging scenarios, demand during the emplacement and development period of the operation and monitoring phase could range from about 0.27 million to about 0.59 million cubic meters (220 to 480 acre-feet) per year. The first 3 years of the monitoring portion of the operation and monitoring phase would require water at a rate varying from 0.2 million to 0.25 million cubic meters (160 to 200 acre-feet) per year. The closure phase would require about 0.099 million to 0.11 million cubic meters (80 to 90 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the

Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by two methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water

During the initial construction period, the estimated water demand from the Jackass Flats Hydrographic Area would be about 0.53 million to about 0.55 million cubic meters (430 to 450 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 0.34 million cubic meters (280 acre-feet) a year (DOE 1998n, Table 11-2, page 11-6)]. This quantity is very similar to the roughly 0.49 million cubic meters (400 acre-feet) withdrawn from the Jackass Flats basin in 1996 (see Chapter 3, Table 3-15). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-16), during which elevation decreases as large as 12 centimeters (4.8 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

During the continuing construction, operation, and monitoring period, groundwater withdrawal rates would increase as listed in Table 4-10. When combined with the ongoing demand from the Nevada Test Site, these rates would be sufficiently larger than those tracked from current activities (see Chapter 3, Table 3-15).

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (Thiel 1997, page 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 0.37 million cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 0.72 million cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 0.72 million cubic meters (580 acre-feet). The highest estimated water demand during the continuing construction, operation, and monitoring period would not exceed this lowest estimate of perennial yield, and it would represent only about 12 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (Turnipseed 1992, pages 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 0.72 million cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 0.72 million cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 0.72 million cubic meters from the western portion of Jackass Flats would be unlikely to cause

a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be too small to estimate or detect.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction period would be about 0.55 million cubic meters (450 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [0.72 million cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. However, repository water demands during the emplacement and development period (Table 4-10), when combined with the baseline demands from Nevada Test Site activities, would exceed the lowest perennial yield estimate under the low thermal load scenario for all packaging scenarios. The combined water demand under either the high or intermediate thermal load scenario would not exceed the lowest estimates of perennial yield. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek Ranch sub-basin, the heaviest water demand is in the Amargosa Desert. Over the long term, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (Buqo 1999, pages 37 and 51). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 0.55 million cubic meters (450 acre-feet) a year] and the operation and monitoring phase [about 0.93 million cubic meters (750 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities. Routine monitoring and maintenance activities would involve minimal water needs and, from a duration standpoint, would occupy most of the operation and monitoring phase.

The annual demand during closure for the high thermal load would be about one-third of that described for the high thermal load during the continuing construction, operation, and monitoring period and, similarly, would have minor impacts on groundwater resources.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Performance Confirmation

Performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance and sustained traffic could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

The desert tortoise, a threatened species, would continue to receive special consideration during land-disturbing activities at the site. DOE would continue to work with the Fish and Wildlife Service and implement the terms and conditions of the Biological Opinion for site characterization activities (Buchanan 1997, pages 19 to 24) to minimize impacts to desert tortoises at the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist of radioactive noble gases, principally isotopes of krypton and radon (TRW 1999a, page 75; see Section 4.1.2). These gases do not accumulate in the environment. The small quantities released would result in very small doses to plants and animals as the gases dispersed in the atmosphere. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). In a similar manner, assumed doses to plants and animals would be small and impacts from those doses would be unlikely to affect the population of any species because the doses would be much lower than the 100-millirad-per-day limit [for which there is no convincing evidence that chronic radiation exposure will harm plant or animal

populations (IAEA 1992, page 54)]. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary between the thermal load scenarios (Table 4-11).

Table 4-11. Land cover types in the analyzed land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

	Total area		Area to be disturbed[d]		
Land cover type[c]	In Nevada	In the analyzed withdrawal area	Low thermal load	Intermediate thermal load	High thermal load
Blackbrush	9,900	140	0.36	0.02	0.02
Creosote-bursage	15,000	300	1.11	0.72	0.62
Mojave mixed scrub	5,700	120	0.03	0.86	0.80
Sagebrush	67,000	16	0	0	0
Salt desert scrub	58,000	20	0	0	0
Previously disturbed	NA[e]	4	0.48	0.37	0.37
Totals[f]	**NA**	**600**	**2.0**	**2.0**	**1.8**

a. Source: Facility diagrams from TRW (1999b, all) and land cover types maps (Utah State University 1996, Gap Data) and vegetation associations (TRW 1998c, page 9) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. As described in Chapter 2, the excavated rock pile would be in a different location for the low thermal load scenario.
e. NA = not applicable.
f. Totals might differ from sums due to rounding.

Six of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada (Utah State University 1996, Gap Data) occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-11). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-11). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in areas dominated by creosote-bursage and Mojave mixed scrub or blackbrush (under the low thermal load scenario) land cover types. These types are widespread in the analyzed land withdrawal area.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (TRW 1999k, pages 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of

monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of vegetation in disturbed areas.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (TRW 1999k, pages 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (TRW 1999k, page 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area. Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North and South Portal Operations Areas. Wildlife would be attracted to the water in these ponds to take advantage of this

otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (Bechtel 1997, page 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 USC 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (TRW 1999k, pages 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (TRW 1997b, pages 6 to 12; TRW 1999k, page 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (TRW 1998h, pages 3 to 17; TRW 1999k, page 3-12). All but one of the 28 individual relocations and both nest relocations were successful. From 1989 to 1998, five tortoises (including the one unsuccessful relocation) were killed as a result of site characterization activities; all were killed by vehicles on roads (TRW 1999k, page 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases. As required by Section 7 of the Endangered Species Act, DOE has initiated consultations with the Fish and Wildlife Service on the desert tortoise. The result of these consultations will be a Fish and Wildlife Service Biological Opinion containing terms and conditions for protection of the desert tortoise during repository construction and operation.

The bald eagle (threatened) and peregrine falcon (endangered, but proposed for delisting) have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, low, moderate, or high, as listed and described in Table 4-12.

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- Soil recovery from disturbances

Table 4-12. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 2 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 2 square kilometers = 500 acres.

- Potential for spreading contamination by relocating contaminated soils (if present)
- Structural stability of existing soils and their ability to support the proposed activities

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removes vegetation or otherwise breaks up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities at the repository during the construction and operation and monitoring phases would disturb no more than about 2 square kilometers (500 acres) of land, including the excavated rock (see Chapter 2).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (TRW 1999l, pages 6 and 7). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during the phases of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DOE 1989a, pages 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DOE 1989a, all; DOE 1995g, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DOE 1989a, page 17; DOE 1995g, page 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would generally remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

Contamination

Based on characterization efforts and activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a spill prevention and control plan [Kiewit (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from performance confirmation, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Performance Confirmation

Land disturbances associated with performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region. Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if possible or, if it was not possible, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction period and the continuing construction, operation, and monitoring period, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 2 square kilometers (500 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified 826 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (TRW 1999m, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, muck and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources. Because the proposed locations of facilities and support areas are away from known archaeological sites, no direct impacts to known resources would occur.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991

indicate that human activities and increased access could result in harmful effects, both advertent and inadvertent, to these fragile resources (TRW 1999m, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (TRW 1999m, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (TRW 1999m, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuance of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of "cultural resource," incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (Stoffle et al. 1990, all; AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion

into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region and in the communities where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE established a bounding case to examine the maximum potential employment levels it would need to implement design features and packaging scenarios. The combination of the low thermal load scenario and the uncanistered packaging scenario would produce the highest incremental change in employment and have the greatest potential to affect the environment.

The analysis determined that no great socioeconomic impacts to any of the areas in the region of influence would be likely. Employment and population changes in the region of influence would not exceed one-half of 1 percent between the projected baseline (employment without the repository project) and the increase from the maximum employment case of the project.

4.1.6.1 Socioeconomic Impacts from Performance Confirmation

The level of employment for performance confirmation activities would be similar to or less than the current level for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be imperceptible, there would be no meaningful impacts to housing or community services.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

In 2006 and 2007, the peak years of employment during the initial construction period, about 1,640 workers would be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes by place of residence during the construction phase. Incremental

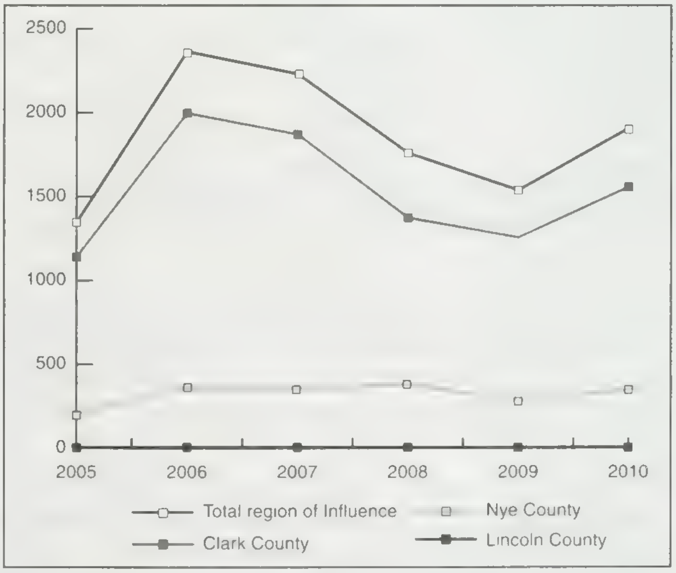


Figure 4-2. Increases in regional employment by place of residence during construction phase and onset of operation and monitoring phase: 2005 to 2010.

employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 2,360 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 946,000 to slightly less than 948,000, a change of less than one-quarter of 1 percent. Table 4-13 summarizes repository peak year employment during the initial construction period by employment category. Table 4-14 lists the expected residential distribution of construction phase workers, which in the first year would exceed 1,600 workers (2006). The table also lists the estimated peak number of indirect jobs created in these communities. These tables do not list Lincoln County because historically no workers have resided there. DOE expects that few, if any, repository employees would live in Lincoln County due to the long commute (TRW 1998d, all).

Table 4-13. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs	Indirect jobs	Total jobs
Clark County			
Indian Springs	48	29	72
Rest of Clark County	1,270	780	1,925
Clark subtotals	*1,318*	*809*	*1,997*
Nye County			
Amargosa Valley	22	5	25
Beatty	3	1	4
Pahrump area	294	68	333
Nye subtotals	*319*	*74*	*362*
Totals	***1,637***	***883***	***2,359***[d]

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (1994b, all).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.
c. Employment in 2006 includes 161 current workers.
d. Does not include the 161 current workers.

Table 4-14. Repository direct workforce during construction phase by expected county of residence: 2005 to 2009.[a,b]

County	2005	2006	2007	2008	2009
Clark	795	1,317	1,093	1,093	1,128
Nye	193	320	311	267	274
Totals	**988**	**1,637**	**1,404**	**1,360**	**1,402**

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.

Construction employment would begin to decline in 2008; in 2010 operational employment would start to increase and would peak in 2012. Employment after 2012 would be essentially stable with an average annual workforce of about 1,600 through 2035. Although operational phase peak employment would occur in 2012 (about 1,780 workers), the overall peak in incremental regional employment related to repository activities would occur earlier, in 2010. Usually the creation of indirect jobs and associated population increases occur after the creation of direct jobs. In this case, the region would still be experiencing the results of the incremental jobs created during the initial construction period. The net increase of about 140 peak year operational jobs over the peak year construction employment level would not affect the regional economy as noticeably as when the relatively small number of site characterization workers increased to more than 1,600 construction workers.

As mentioned above, in 2012, the peak year of employment during the continuing construction, operation, and monitoring period, about 1,780 workers would be employed on the Yucca Mountain Repository Project (TRW 1999a, Section 6; TRW 1999b, Section 6). As a consequence, the analysis included information on repository residential distribution and employment levels for 2010.

Table 4-15 lists the expected residential distribution of repository workers in the peak year, 2010. The table also lists the estimated number of indirect jobs created in these communities during 2010. The direct and indirect employment in the region of influence would peak with the addition of approximately 1,900 workers. This would result in a total increase in employment from the projected baseline of about 1,002,000 to about 1,004,000, a change of less than one-quarter of 1 percent. Table 4-16 summarizes repository employment through the first 35 years of the operation and monitoring phase by employment category. These tables do not list Lincoln County because historically no workers have resided there. As mentioned above, DOE expects that few workers would live in Lincoln County due to the long commute (TRW 1998d, all). Figure 4-3 shows the direct and indirect regional employment differences between the maximum employment case and the projected baseline.

Table 4-15. Expected peak year (2010) increases in operations employment in selected communities in Nye and Clark Counties.

Location	Direct jobs[a]	Indirect jobs	Total jobs
Clark County			
Indian Springs	64	11	56
Rest of Clark County	1,326	286	1,501
Clark subtotals	*1,421*	*297*	*1,557*
Nye County			
Amargosa Valley	23	3	24
Beatty	3	0	3
Pahrump	311	37	319
Nye subtotals	*337*	*40*	*346*
Totals	***1,727***	***337***	***1,903***[b]

a. Employment in 2010 includes 161 current workers.
b. Does not include the 161 current workers.

Table 4-16. Repository direct employment during operation and monitoring phase by county of residence: 2010 to 2035.

County	2010	2015	2020	2025	2030	2035
Clark total	1,390	1,365	1,379	1,365	1,322	1,161
Nye total	337	332	335	332	322	282
Totals	**1,727**	**1,697**	**1,714**	**1,697**	**1,644**	**1,443**

The completion of emplacement activities would result in a decline from about 1,560 emplacement workers in 2031 to about 1,440 decontamination and decommissioning workers from 2034 to about 2036 to 120 monitoring and maintenance workers from 2037 to 2110 employed at the Yucca Mountain site. However, even without the repository, the baseline projection predicts a continued increase in employment in the region of influence. If the present economic growth continued in the region of influence, it could absorb declines in the repository workforce.

After the completion of emplacement and decontamination of surface facilities, an annual employment of about 120 workers would be required for ongoing monitoring and maintenance activities. These activities could last as few as 26 years or as many as 276 years. This study assumed that monitoring would end in 2110, 100 years after the start of emplacement. Because monitoring and maintenance activities would require so few workers, no socioeconomic impacts would be likely.

The closure phase would be from 2110 to between 2116 and 2124, depending on the thermal load scenario. Projected peak employment for this phase would be approximately 520 workers (TRW 1999a, Section 6; TRW 1999b, Section 6). Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate changes to the labor force and economic measures of less than one-half of 1 percent. There probably would be no perceptible repository-induced changes to the baseline employment in the region of influence. Regional impacts during the closure phase probably would be small.

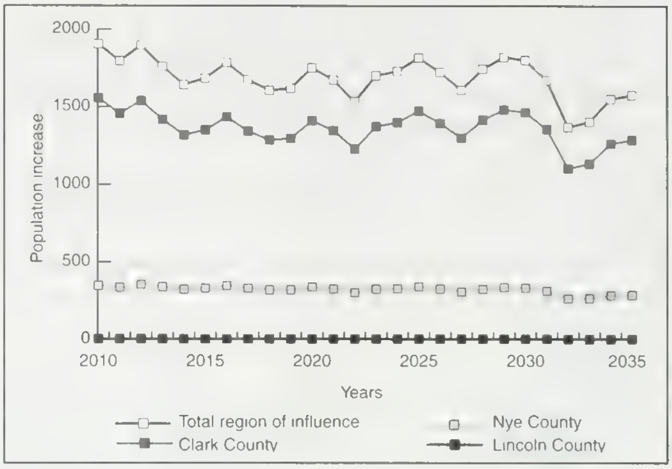


Figure 4-3. Increases in regional employment from operation and monitoring phase: 2010 to 2035.

4.1.6.2.2 *Impacts to Population*

From 2010, the projected year of peak employment, through 2035, the projected regional population will grow from about 1.9 million to more than 2.7 million people. The peak year population contribution attributable to the repository would be fewer than 4,000 people, a very small fraction of 1 percent. As a consequence, the Yucca Mountain Repository Project would be unlikely to alter the population growth to a great degree in the region of influence. Figure 4-4 shows the projected population increase as a result of the repository project.

Table 4-17 lists estimated incremental population increases that would occur as a result of repository activities to Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental population increase in Clark County would be almost imperceptible.

Table 4-17. Maximum expected population increase (2030).

Location	Population increase
Clark County	
Indian Springs	108
Rest of Clark County	2,882
Clark total	**2,990**
Nye County	
Amargosa Valley	50
Beatty	7
Pahrump	669
Nye total	**726**

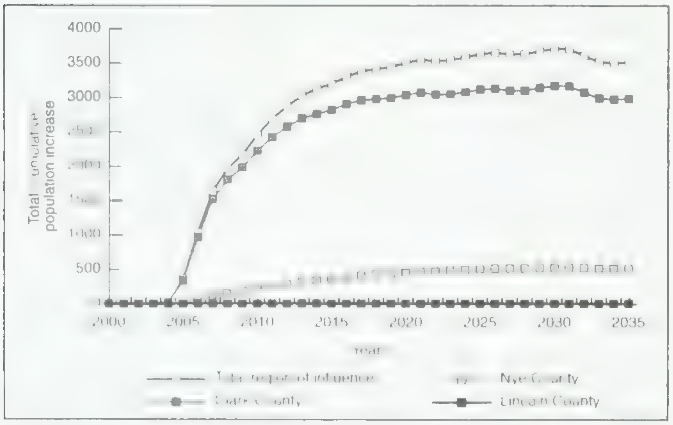


Figure 4-4. Regional population increases from construction and operations: 2000 to 2035.

The increase in the Nye County population would be less than 2 percent of the projected total population for the peak year for potential repository impacts. The Yucca Mountain Repository would not alter the population growth rate in Clark County in a measurable degree. Population growth associated with the repository would be more evident in Nye County. However, because the increases would occur over a long period, about 25 years, Nye County could accommodate them.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-18 lists changes in economic measures that would result from repository activities during the construction phase (expressed in 1992 dollars). The increases in real disposable income would peak in 2007 with an increase of about $57 million, while increases in Gross Regional Product would peak in 2006 at about $98 million. Regional expenditures by state and local governments would peak at $5.8 million in 2009. Economic measures for the region of influence would increase by less than one-quarter of 1 percent over the projected baseline (economic measures without the repository project).

Table 4-18. Increases in economic measures from repository construction: 2005 to 2009 (thousands of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Personal income	28,000	52,100	53,500	44,600	43,500
Gross Regional Product	46,500	84,000	79,100	59,400	47,800
State and local government expenditures	800	2,500	4,000	4,700	5,300
Nye County					
Personal income	1,700	3,100	3,100	2,400	2,800
Gross Regional Product	7,600	13,800	13,300	10,600	9,500
State and local government expenditures	100	200	300	400	500
Lincoln County					
Personal income	100	200	200	200	200
Gross Regional Product	100	100	100	100	100
State and local government expenditures	0	0	0	0	0
Total region of influence					
Personal income	29,800	55,400	56,800	47,200	46,500
Gross Regional Product	54,200	97,900	92,500	70,100	57,400
State and local government expenditures	900	2,700	4,300	5,100	5,800

a. Totals might differ from sums due to rounding.

GROSS REGIONAL PRODUCT

Value of goods and services produced in the region of influence.

Table 4-19 lists the changes in economic measures that would result from the repository project during the operation and monitoring phase. Increases in Gross Regional Product and in real disposable income would peak in 2029-2030, at about $70 million and $83 million, respectively. Increases in regional expenditures by state and local governments under the maximum employment case would also peak in 2030 at about $11 million. Economic measures for the region of influence would increase by less than one-half of 1 percent over the projected baseline.

4.1.6.2.4 *Impacts to Housing*

Repository-generated impacts to housing availability from changes in the population in the region of influence would be small. Given the size of the regional workforce, the number of workers inmigrating to work on the repository would be unlikely to be measurable.

The region of influence has an adequate supply of undeveloped land to meet future demands. Throughout most of the 1990s, the Bureau of Land Management has conducted land exchanges in Clark County. These exchanges have typically involved a trade of environmentally sensitive land outside the county for Bureau land in the county. The land in Clark County moves to the private sector for sale to land developers. This policy has helped to accommodate the population growth in the Las Vegas area.

Table 4-19. Increases in economic measures from emplacement and development activities: 2010 to 2035 (thousands of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2035
Clark County						
Personal income	53,200	57,400	64,300	70,300	74,700	73,000
Gross Regional Product	53,000	46,900	52,100	56,500	57,800	49,000
State and local government expenditures	5,900	7,700	8,400	8,800	9,100	8,800
Nye County						
Personal income	4,000	5,400	6,700	7,600	8,300	8,500
Gross Regional Product	11,000	10,600	11,400	11,900	11,800	10,000
State and local government expenditures	700	1,100	1,400	1,600	1,700	1,700
Lincoln County						
Personal income	200	200	200	200	300	200
Gross Regional Product	100	100	100	100	100	100
State and local government expenditures	0	100	100	100	100	100
Total region of influence						
Personal income	57,400	63,000	71,200	78,100	83,300	81,700
Gross Regional Product	64,100	57,600	63,600	68,500	69,700	59,100
State and local government expenditures	6,600	8,900	9,900	10,500	10,900	10,600

a. Totals might differ from sums due to rounding.

Workers and dependents who migrated to work on the repository probably would live in the many communities of Clark County, thereby dispersing the increased demand for housing. Southern Nye County, particularly Pahrump, would also experience some demand for housing. However, because the change in population would occur steadily over a long period, the county would be able to accommodate increases in housing demands. In Lincoln County, little or no demand would be likely, so housing availability would not be an issue.

4.1.6.2.5 *Impacts to Public Services*

Repository-generated impacts to public services from changes in the population in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated job growth in the region. Even with the addition of repository jobs, the annual regional growth rate would increase by less than 2 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, inmigrating workers probably would live in the many communities of Clark County, thereby dispersing the increased demand for public services. Southern Nye County, particularly Pahrump, also would experience some demand for public services. However, because the change in population would occur steadily over a long period, the county would be able to meet education, law enforcement, and fire protection demands. Impacts to public services would be unlikely in Lincoln County.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes short-term (prior to the completion of repository closure) health and safety impacts to workers (occupational impacts) and to members of the public from performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and

emplacement of spent nuclear fuel and high-level radioactive waste materials; and monitoring of the condition and performance of the waste packages. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in construction, excavation, and operations activities.

The evaluation used engineering estimates of equivalent full-time years worked during each phase along with standard statistics on industrial accidents and incidents to estimate impacts to workers from nonradiological hazards. It used a similar approach for radiological worker hazards. The evaluation used engineering estimates of pollutant releases from repository operations along with standard modeling techniques to estimate impacts to members of the public.

The types of human health and safety impacts estimated for workers would include those from industrial hazards, exposure to radiation and radioactive material, and exposure to hazardous nonradioactive material. The hazardous nonradioactive materials would be cristobalite and erionite, naturally occurring minerals in the rock (welded tuff) of the planned repository location. All of the estimated human health impacts to members of the public are based on airborne exposures to naturally occurring radioactive and hazardous materials. The radiological doses and hazardous material concentrations on which the human health impacts are based are described in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. In addition, it contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Performance Confirmation (2001 to 2005)

Performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring cristobalite and erionite generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operations and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (TRW 1994a, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.000001. No latent cancer fatalities (less than 0.007) would be likely in the potentially exposed population (see Section 4.1.7.2.2).

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction (2005 to 2010)

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction period (2005 to 2010). During this period, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting (such as falling or tripping) in which they would be working using statistics for similar kinds of operations and estimates of the total number of full-time equivalent worker years that would be involved in the activities. The statistics that the analysis used are from the DOE Computerized Accident/Incident Reporting and Recordkeeping System (DOE 1999c, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

The analysis based its estimates for the number of full-time worker years for the construction phase on the current repository design concepts described in Chapter 2. Estimates range from about 5,200 to about 6,300 worker years depending on the thermal load and packaging scenario (Appendix F, Table F-1). Table 4-20 lists estimated potential impacts from normal industrial hazards for involved and noninvolved workers for the construction phase. The table lists three types of industrial safety impacts: total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities. (See the discussions in Appendix F, Section F.2.2.)

Table 4-20. Estimated impacts to workers from industrial hazards during initial construction period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved workers									
Total recordable cases	290	240	250	300	250	260	300	250	260
Lost workday cases	140	120	120	140	120	120	140	120	120
Fatalities	0.14	0.11	0.12	0.14	0.12	0.12	0.14	0.12	0.12
Noninvolved workers									
Total recordable cases	50	41	42	50	41	42	50	41	42
Lost workday cases	24	20	21	24	20	21	24	20	21
Fatalities	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
All workers (totals)[f]									
Total recordable cases	340	280	290	350	290	300	350	290	300
Lost workday cases	160	140	140	160	140	140	170	140	140
Fatalities	0.18	0.15	0.16	0.18	0.16	0.16	0.18	0.16	0.16

a. Source: Appendix F, Tables F-7 and F-8.
b. The analysis assumed that construction phase would last 44 months for surface activities and 60 months for subsurface activities.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. Totals might differ from sums due to rounding.

The surface facilities that would be required to handle each packaging scenario would be different, so the industrial safety impacts for construction would be different. Appendix F, Tables F-7 and F-8, contains industrial hazard impact tables for surface and subsurface workers.

Estimated fatalities would be of the magnitude of 0.2 for all scenarios. Industrial safety impacts (including total recordable cases and lost workday cases) would be largest for the uncanistered packaging scenario due to the more extensive surface facilities required and, hence, more worker years for construction.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials are present at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both occur in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository operations. Cristobalite, which would occur at the repository level, would be released during tunneling operations. It could also be released with wind-blown dust from the excavated rock pile.

Dust generated during tunneling would come from welded tuff, which consists largely of silica-based minerals. Crystalline silica is a highly structured form of silica that includes quartz and cristobalite. It is a known causative agent for the disease called *silicosis,* which is a destructive lung condition caused by deposition of particulate matter in the lungs and characterized by scarring of lung tissue. It is contracted by prolonged exposure to high levels of respirable silica dust or to acute levels of respirable silica dust (EPA 1996a, Chapter 8). The welded tuff has an average cristobalite content of between 18 and 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably will overestimate the airborne cristobalite concentration, because studies of both ambient and occupational airborne crystalline silica have shown that most airborne crystalline silica is coarse and not respirable, and that larger particles will deposit rapidly on the surface (EPA 1996a, page 3-26).

The International Agency for Research on Cancer has classified crystalline silica, when inhaled in the form of quartz or cristobalite from occupational sources, as a Class 1 (known) carcinogen (IARC 1997, pages 207 and 208). The Environmental Protection Agency has noted an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, pages 8-7 to 8-9). To date, the Environmental Protection Agency has not issued the factors needed to estimate the risk of cancer from crystalline silica exposures.

The dust from mechanical rock excavation and dust pickup from the excavated rock pile would consist of a range of particle sizes. Dust particles with an aerodynamic diameter smaller than 10 micrometers have little mass and inertia in comparison to their surface area; therefore, they can remain suspended in dry air for long periods and humans can inhale them. DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, subsurface workers would have to wear respirators until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block as required for the low thermal load scenario. Erionite forms wool-like fibrous masses with a maximum fiber length of about 50 micrometers. The International Agency for Research on Cancer has determined that erionite is a carcinogen for humans, based on the very high mortality observed in three Turkish villages where erionite is mined (IARC 1987, all). DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and workers would be required to wear respiratory protection until acceptable conditions were reestablished. Appendix F, Section F.1.2, contains additional information on the impacts associated with inhalation of crystalline silica, cristobalite, and erionite.

Radiological Health Impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during this phase would be from two sources: exposure to and inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (TRW 1999o, Sections 4 and 5). Radon-222 is a noble gas produced by the radioactive decay of naturally occurring uranium-238 in the rock. Because it is a noble gas, radon could emanate from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8).

Studies during Exploratory Studies Facility activities indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface, 40 millirem per year in the Amargosa Valley region (see Chapter 3, Table 3-28). This analysis considers the underground ambient radiation dose to be part of the involved worker occupational exposure.

Workers in surface facilities would be exposed to airborne emissions of radon-222 and its decay products released in subsurface exhaust ventilation air. Spent nuclear fuel and high-level radioactive waste would not be present at the site during the construction phase and so would not contribute to radiological impacts.

Table 4-21 lists estimated potential doses and radiological health impacts for the 5 years of the construction phase to involved workers and noninvolved workers, and the sum for all workers. It lists estimated doses and radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). This conversion factor is based on a widely accepted international recommendation (ICRP 1991, page 22) and has been accepted for use by Federal agencies. The tables that follow list radiological health impacts for individuals as the increase in the probability of a latent cancer fatality occurring after the receipt of a dose for the maximally exposed individual worker.

Table 4-21. Estimated doses and radiological health impacts to workers during initial construction period.[a,b]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved workers			
Maximally exposed worker dose (millirem)	770	860	860
Latent cancer fatality probability	0.0003	0.0003	0.0003
Collective dose (person-rem)	350	420	420
Latent cancer fatality incidence	0.14	0.17	0.17
Noninvolved workers			
Maximally exposed worker dose (millirem)	580	640	640
Latent cancer fatality probability	0.0002	0.0003	0.0003
Collective dose (person-rem)	70	78	78
Latent cancer fatality incidence	0.03	0.03	0.03
All workers (totals)[c]			
Collective dose (person-rem)	420	500	500
Latent cancer fatality incidence	0.17	0.20	0.20

a. Source: Appendix F, Tables F-9 and F-10.
b. The construction phase would last 5 years. Results are for subsurface workers.
c. Totals might differ from sums due to rounding.

Radiological health impacts to populations are listed as the number of latent cancer fatalities estimated to occur in the exposed population.

During the initial construction period, radiological health impacts to the surface facility workforce would be much smaller than those to the subsurface facility workforce, so the numbers in Table 4-21 are those for subsurface workers (see Appendix F, Table F-5).

Table 4-21 indicates that the projected increase in the number of latent cancer fatalities for workers would be low (about 0.2); the calculated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be low (less than about 0.0003).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Table 4-1 lists estimated annual average concentrations of cristobalite at the site boundary where members of the public could be exposed during the construction phase. The analysis estimated concentrations of less than 0.025 microgram per cubic meter for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. The analysis estimated doses and radiological health impacts for the offsite maximally exposed individual and the potentially involved population. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the largest annual dose and resultant radiological health impact. This location would be 20 kilometers (about 12 miles) south of the repository site. Section 4.1.2.2.2 provides additional information on the estimates of public doses. Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Chapter 3, Section 3.1.8).

Table 4-22 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction period. The values in the table indicate that radiological health impacts to the public from repository construction would be very small (0.006 latent cancer fatality for each of the thermal load scenarios). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be about 0.000001 over the 5-year phase.

Table 4-22. Estimated doses and radiological health impacts from radon-222 to the public during the initial construction period.[a,b]

Dose or health effect	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] dose (millirem)	2.1	2.5	2.5
Latent cancer fatality probability	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
Collective dose (person-rem)[d]	11	13	13
Latent cancer fatality incidence	0.0057	0.0066	0.0066

a. Source: Table 4-2.
b. The initial construction period would last 5 years.
c. The individual was assumed to maintain continuous residence 20 kilometers (12 miles) south of the repository.
d. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) of the repository.

4.1.7.3 Occupational and Public Health and Safety Impacts for the Continuing Construction, Operation, and Monitoring Period (2010 to 2110)

This section discusses estimates of health and safety impacts to workers and members of the public for the operation and monitoring phase. The analysis assumed a 24-year period for the receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent 22-year period for drift development. A 76-year monitoring period would begin after the completion of emplacement. However, the monitoring period could be as short as 26 years and as long as 276 years (see Section 4.1). Appendix F, Table F-24, lists radiological health impacts for the shorter and longer monitoring periods.

4.1.7.3.1 *Occupational Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. Table 4-23 summarizes health and safety impacts from common industrial hazards for the operation and monitoring phase. DOE performed separate analyses for surface operations, subsurface emplacement operations, subsurface drift development operations, and monitoring activities, and summed the values to obtain the results listed in this table. Appendix F (Tables F-11, F-12, and F-13) contains results of the impact analysis for each subphase.

The analysis predicted a range of 1.3 to 1.6 fatalities for the various combinations of thermal load scenarios and packaging scenarios. The largest number of workers (see Appendix F, Table F-1) and, therefore, the largest industrial health and safety impacts would be associated with the uncanistered packaging scenario.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during the operation and monitoring phase.

Radiological Health Impacts. This section discusses the estimates of the radiological health impacts to workers for the operation and monitoring phase. The overall radiological health impacts, which are listed in Table 4-24, are a combination of impacts to surface workers during operation, impacts to subsurface workers during operations, and impacts to surface and subsurface workers during monitoring.

Table 4-23. Estimated impacts to workers from industrial hazards during the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load UC[c]	High thermal load DISP[d]	High thermal load DPC[e]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
Involved									
TRC[f]	1,360	1,150	1,160	1,360	1,150	1,160	1,400	1,180	1,200
LWC[g]	710	610	620	710	610	620	730	640	640
Fatalities	1.1	0.88	0.89	1.1	0.88	0.89	1.1	0.90	0.92
Noninvolved									
TRC	500	450	450	500	450	450	500	450	450
LWC	250	220	220	250	220	220	250	220	220
Fatalities	0.49	0.43	0.43	0.49	0.43	0.43	0.49	0.42	0.43
All workers (totals)[h]									
TRC	1,860	1,590	1,600	1,860	1,600	1,610	1,900	1,630	1,650
LWC	960	830	840	960	840	840	980	860	860
Fatalities	1.6	1.3	1.3	1.6	1.3	1.3	1.6	1.3	1.4

a. Source: Appendix F; sum of impacts listed in Tables F-11, F-12, F-13, F-19, F-20, and F-21.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases of accident or injury.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

Table 4-24. Estimated dose and radiological health impacts to workers for the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load UC[c]	High thermal load DISP[d]	High thermal load DPC[e]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
Involved									
MEI dose[f]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h]	8,120	5,330	5,380	8,450	5,660	5,710	8,530	5,740	5,790
LCF incidence	3.2	2.1	2.2	3.4	2.3	2.3	3.4	2.3	2.3
Noninvolved									
MEI dose	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	350	330	330	380	360	360	400	390	390
LCF incidence	0.14	0.13	0.13	0.15	0.14	0.14	0.16	0.15	0.15
All workers (totals)[i]									
CD	8,470	5,660	5,710	8,830	6,020	6,070	8,930	6,130	6,180
LCF incidence	3.3	2.2	2.2	3.6	2.4	2.4	3.6	2.5	2.5

a. Source: The maximally exposed individual and latent cancer fatality probabilities are the maximums from Tables 4-25, 4-26, and 4-27. The collective dose and latent cancer fatality incidence are summed from the same tables.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem. The subsurface facilities workers could incur the dose shown during the monitoring period.
g. LCF = latent cancer fatality.
h. CD = collective dose (person-rem).
i. Totals might differ from sums due to rounding.

With respect to overall radiological health impacts, the estimated health impacts to workers for the 100-year operation and monitoring phase would range from 2 to 4 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would be about the same as those from normal background radiation exposure in the Amargosa Valley region over a 70-year lifetime (about 25,000 millirem) during the 100-year operation and monitoring phase.

Tables 4-25 and 4-26 list health impacts to surface and subsurface workers, respectively, for 24 years of operations activities. Radiological health impacts to surface workers would be independent of the thermal load scenarios, and impacts to subsurface workers would be independent of the packaging scenario.

Table 4-25. Estimated dose and radiological health impacts to surface facility workers for the 24-year operation period.[a]

Worker group and impact category	Packaging scenario[b]		
	UC	DISP	DPC
Involved workers			
Maximally exposed worker dose (millirem)	9,600	9,600	9,600
LCF[c] probability	0.004	0.004	0.004
Collective dose (person-rem)	5,170	2,460	2,500
LCF incidence	2.1	1.0	1.0
Noninvolved workers			
Maximally exposed worker dose (millirem)	600	600	600
LCF probability	0.0002	0.0002	0.0002
Collective dose (person-rem)	100	90	90
LCF incidence	0.04	0.04	0.04
All workers (totals)[d]			
Collective dose (person-rem)	5,270	2,550	2,590
LCF incidence	2.1	1.0	1.0

a. Calculated from full-time equivalent worker year values in Appendix F, Table F-1 and dose rate values in Table F-5.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

Table 4-26. Estimated dose and radiological health impacts to subsurface facilities workers during the 24-year operation period.[a]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved			
Maximally exposed worker dose (millirem)[b]	7,010	7,630	7,630
LCF[c] probability	0.003	0.003	0.003
Collective dose (person-rem)	900	950	1,010
LCF incidence	0.36	0.38	0.40
Noninvolved			
Maximally exposed worker dose (millirem)[b]	980	1,270	2,280
LCF probability	0.0004	0.0005	0.0009
Collective dose (person-rem)	120	120	140
LCF incidence	0.05	0.05	0.06
All workers (totals)[d]			
Collective dose (person-rem)	1,020	1,070	1,150
LCF incidence	0.41	0.43	0.46

a. Source: Appendix F; sum of impacts listed in Tables F-14, F-15, F-16, F-17, and F-18. The impacts listed would result from work lasting 22 to 24 years.
b. The subsurface facilities emplacement workers could incur the dose shown during the 24-year operation period (the development worker's maximum worker dose would be lower).
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

The basic dose rate data (Appendix F, Table F-5) used to calculate radiological impacts are conservatively high, particularly for workers in surface facility operations, and tend to overestimate potential impacts. These estimates are sufficiently conservative to include potential doses from other activities such as handling low-level radioactive waste generated during repository operations. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement, and subsurface monitoring activities (see Tables 4-25, 4-26, and 4-27). Radiological health impacts to workers would be highest for the combination of the uncanistered package scenario and the low thermal load scenario, with estimated radiological health impacts varying by about 50 percent from highest to lowest. Radiological health impacts from this combination of scenarios would be highest because it would involve the highest number of worker years. The variations are not large for a given shipping package scenario because impacts to subsurface workers would not depend on the shipping package scenario.

The largest component of the radiological impacts to subsurface workers during emplacement would be from inhalation of radon-222 and its decay products, particularly during the postemplacement monitoring period (see Appendix F, Table F-23).

Decontamination, Monitoring, and Maintenance Activities (2034 to 2110). The monitoring and maintenance activities of the operation and monitoring phase would last for 76 years and involve two types of activities leading to potential radiological health impacts. They are the decontamination of the surface facilities, which would take 2 to 3 years at the beginning of the monitoring period, and subsurface monitoring and maintenance activities. Table 4-27 lists estimated dose and radiological health impacts to workers for the surface facilities decontamination activities and the 76-year monitoring period.

Table 4-27. Estimated dose and radiological health impacts to workers for the 3-year decontamination period and the 76-year monitoring and maintenance period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[f] (millirem)	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h] (person-rem)	2,050	1,990	1,980	2,330	2,250	2,260	2,350	2,270	2,280
LCF incidence	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.0	1.0
Noninvolved									
MEI dose (millirem)	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD (person-rem)	120	120	120	150	150	150	160	160	160
LCF incidence	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
All workers (total)[i]									
CD (person-rem)	2,170	2,110	2,100	2,480	2,400	2,410	2,510	2,430	2,440
LCF incidence	1.0	1.0	1.0	2.1	1.0	1.0	1.1	1.0	1.0

a. Sources: Appendix F, Tables F-22 and F-23.
b. Monitoring period impacts would be independent of the packaging scenario; surface facility decontamination impacts would depend on the packaging scenario.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem.
g. LCF = latent cancer fatality.
h. CD = collective dose.
i. Totals might differ from sums due to rounding.

Appendix F, Table F-22 lists the radiological health impacts associated with surface facility decontamination operations. The impacts would vary with the packaging scenario because of differences in the surface facility design to accommodate the different types of shipping packages.

Monitoring and maintenance would involve both surface and subsurface workers; however, the dose to surface workers would be very low in comparison to those to subsurface workers. Therefore, essentially all the radiological impacts would be to subsurface workers (see Appendix F, Table F-5 footnotes). Appendix F, Table F-23, lists doses and radiological health impacts to subsurface workers for the 76-year monitoring period. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. In addition, Appendix F describes dose and radiological health estimates for workers for a shorter monitoring period of 26 years and for a longer monitoring period of 276 years (see Appendix F, Table F-24).

4.1.7.3.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.015 microgram per cubic meter or less for all thermal load scenarios. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from the operation and monitoring phase could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.001 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the continuing construction, operation, and monitoring period. Table 4-28 lists these doses and potential radiological health impacts to the public for that period.

Table 4-28. Estimated total dose and radiological health impacts over 50 years to the public for continuing construction, operation, and monitoring period.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	49	58	132
Latent cancer fatality probability	2.45×10^{-5}	2.3×10^{-5}	6.6×10^{-5}
Collective dose[c] (person-rem)	259	310	700
Latent cancer fatality incidence	0.13	0.15	0.35

a. Source: Tables 4-4 and 4-5.
b. Exposed for a 70-year lifetime; assumed first 24 years during operation and last 46 years during monitoring.
c. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) for 100 years of operation and monitoring.

Potential radiological health impacts to the public from radionuclides released during the operation and monitoring phase would be low, with 0.13 to 0.35 latent cancer fatality estimated for the thermal load scenarios. The probability of a latent cancer fatality to the maximally exposed individual would be about 0.00005 or less.

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure (2110 to 2125)

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase would depend on the thermal load scenario. The values used for impact estimates are 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.

4.1.7.4.1 *Occupational Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. Table 4-29 lists impacts to workers from normal industrial workplace hazards for the closure phase.

Table 4-29. Estimated impacts to workers from industrial hazards during closure phase.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[f]	180	150	150	180	150	150	300	270	270
LWC[g]	85	71	74	85	71	74	140	130	130
Fatalities	0.08	0.07	0.07	0.08	0.07	0.07	0.14	0.13	0.13
Noninvolved									
TRC	28	24	23	28	23	24	41	36	37
LWC	14	11	12	14	11	12	20	18	18
Fatalities	0.03	0.02	0.02	0.03	0.02	0.02	0.04	0.03	0.03
All workers (totals)[h]									
TRC	210	170	170	210	170	170	340	310	310
LWC	99	82	86	99	82	86	160	150	150
Fatalities	0.11	0.09	0.09	0.11	0.09	0.09	0.18	0.16	0.16

a. Source: Appendix F, Tables F-25 and F-26.
b. The closure phase would last for 6, 6, and 15 years for high, intermediate, and low thermal loads, respectively (Jessen 1999a).
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

The estimated number of impacts from industrial hazards for the low thermal load scenario would be about double those for the intermediate and high thermal load scenarios because of the longer time required for closure and the associated larger number of worker years. The estimated number of fatalities would be much less than 1 for all thermal load scenarios.

Naturally Occurring Hazardous Material. Subsurface excavation would not occur during the closure phase, so the potential for exposure of workers to cristobalite and erionite would be much less. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.2 for the construction phase to control and minimize potential impacts to workers.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation emanating from the waste packages. Table 4-30 lists radiological impacts to workers for the closure phase. Because estimated doses and radiological impacts to surface workers would be

Table 4-30. Estimated dose and radiological health impacts to workers during closure phase.[a,b]

Worker group and impact category	High thermal load (6 years)	Intermediate thermal load (6 years)	Low thermal load (15 years)
Involved			
Maximally exposed individual dose[c] (millirem)	2,040	2,370	5,520
Latent cancer fatality probability	0.0008	0.0009	0.002
Collective dose (person-rem)	380	450	1,100
Latent cancer fatality incidence	0.15	0.18	0.44
Noninvolved			
Maximally exposed individual dose[c] (millirem)	1,090	1,340	3,540
Latent cancer fatality probability	0.0004	0.0005	0.001
Collective dose (person-rem)	48	59	160
Latent cancer fatality incidence	0.02	0.02	0.06
All workers (totals)[d]			
Collective dose (person-rem)	430	510	1,260
Latent cancer fatality incidence	0.17	0.20	0.50

a. Source: Appendix F, Tables F-27, F-28, and F-29.
b. Closure phase would last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively (Jessen 1999a, all).
c. The subsurface facilities workers could incur the dose listed during the closure phase.
d. Totals might differ from sums due to rounding.

much smaller than those for subsurface workers (see Appendix F, Table F-5 footnotes), the impacts listed in this table are those for subsurface workers, which would be independent of the packaging scenario.

For the closure phase, the estimated number of latent cancer fatalities would range from 0.2 to 0.5. The probability of a latent cancer fatality for the maximally exposed individual worker would be 0.002 or less. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.015 microgram per cubic meter or less were estimated for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-31 lists the estimated dose and radiological health impacts.

Radiological health impacts to the public would be low. The likelihood that the maximally exposed individual would experience a latent cancer fatality would be in the range of 0.000001 to 0.00001. The projected number of latent cancer fatalities would be 0.05 or less. The radiological health impacts to the public would be independent of the packaging scenario. Impacts to the public would be greatest for the low thermal load scenario, and would be about 6 to 7 times greater than for the intermediate and high thermal loads because of the larger radon release associated with the longer closure period for the low thermal load scenario.

Table 4-31. Estimated dose and radiological health impacts to public for the closure phase.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	2.6	3.1	19
Latent cancer fatality probability	1.3×10^{-6}	1.5×10^{-6}	9.4×10^{-6}
Collective dose (person-rem)[c]	13	15	93
Latent cancer fatality incidence	0.0064	0.0076	0.047

a. Source: Table 4-7.
b. For a person maintaining continuous residency during the entire closure phase.
c. Dose to approximately 28,000 individuals living within about 80 kilometers (50 miles).

4.1.7.5 Summary of Impacts to Occupational and Public Health and Safety

This section summarizes the potential human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases for (1) impacts to workers from industrial hazards; (2) radiological health impacts to workers; and (3) radiological health impacts to members of the public. The three project phases would last 111, 111, and 120 years for the high, intermediate, and low thermal load scenarios, respectively. These differences in project duration are due to differences in the length of the closure phase for the three thermal load scenarios as described above.

4.1.7.5.1 *Impacts to Workers from Industrial Hazards in the Workplace for All Phases*

Table 4-32 lists the total impacts to workers from industrial hazards common to the workplace for all phases. For the approximately 110 to 120 years of repository activities, the estimated number of workplace fatalities would range from about 1.5 to 2. The estimated number of lost workday cases due to industrial injury or illness would range from about 1,060 to 1,280, depending on the combination of thermal load scenario and packaging scenario. About half of the industrial impacts would come from surface facility operations during the operation and monitoring phase because of the large number of worker years needed. The next largest contribution would be drift development during the operation and monitoring phase, which would account for as much as 15 percent of the impacts. The differences in impacts for the thermal load and shipping package combinations reflect differences in the number of full-time equivalent workers for the potential combinations.

4.1.7.5.2 *Radiological Impacts to Workers for All Phases*

Table 4-33 lists the total dose and radiological health impacts to workers for all phases. It lists dose and the potential radiological health impact to the maximally exposed individual worker for a 50-year working lifetime, and collective dose and potential radiological health impacts to the worker population for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively. The maximally exposed worker would have a probability of incurring a latent cancer fatality of 0.006 to 0.008 from radiation exposure over a 50-year working lifetime. The total estimated number of latent cancer fatalities in the repository workforce from the radiation exposure during all phases would range from about 2.5 to 4, depending on the combination of thermal load scenario and packaging scenario.

About 50 percent of the total worker radiation dose would be from the receipt, handling, and packaging of spent nuclear fuel in the surface facilities. Radiation from inhalation of radon-222 and its decay products by subsurface workers during construction, development, emplacement, monitoring, and closure

Table 4-32. Estimated impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[e]	1,820	1,540	1,560	1,830	1,550	1,570	1,990	1,700	1,730
LWC[f]	930	800	810	930	810	820	1,010	890	900
Fatalities	1.3	1.1	1.1	1.3	1.1	1.1	1.4	1.2	1.2
Noninvolved									
TRC	570	510	520	570	510	520	590	520	530
LWC	280	250	260	280	250	260	290	260	260
Fatalities	0.54	0.48	0.49	0.54	0.48	0.49	0.55	0.50	0.50
All workers (totals)[g]									
TRC	2,390	2,050	2,080	2,400	2,060	2,090	2,580	2,220	2,260
LWC	1,210	1,050	1,070	1,210	1,080	1,080	1,300	1,150	1,160
Fatalities	1.8	1.6	1.6	1.8	1.6	1.6	2.0	1.7	1.7

a. Source: Sum of impacts listed in Tables 4-20, 4-23, and 4-29.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.

Table 4-33. Estimated dose and radiological health impacts to workers for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[e]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[f] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[g]	8,850	6,060	6,110	9,320	6,530	6,580	10,060	7,270	7,320
LCF incidence	3.5	2.4	2.4	3.7	2.6	2.6	4.0	2.9	2.9
Noninvolved									
MEI dose[e]	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	460	450	450	510	500	500	640	620	620
LCF incidence	0.19	0.18	0.18	0.21	0.20	0.20	0.25	0.25	0.25
All workers (totals)[h]									
CD	9,310	6,510	6,560	9,830	7,030	7,080	10,700	7,890	7,940
LCF incidence	3.7	2.6	2.6	3.9	2.8	2.8	4.3	3.2	3.2

a. Source: Tables 4-21, 4-24, and 4-30.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. MEI dose = maximally exposed individual (surface facility worker) dose, in millirem.
f. LCF = latent cancer fatality.
g. CD = collective dose (person-rem).
h. Totals might differ from sums due to rounding.

would account for about 25 percent of the total worker dose, with another 10 to 15 percent of the total dose coming from subsurface worker exposure to radiation emanating from the waste packages.

Estimated dose and radiological health impacts to workers would be highest for the low thermal load scenario, with estimates 30 to 40 percent higher than those for the high thermal load scenario, because of

the larger number of projected worker years. Dose and radiological health impacts would be one-third more for the uncanistered packaging scenarios than those for the other packaging scenarios because of the larger number of projected worker years. Accordingly, the combination of the low thermal load scenario and the uncanistered packaging scenario would have the highest estimated collective worker dose (10,700 person-rem) and highest estimated radiological impacts (4.3 latent cancer fatalities) over 120 years of repository activities.

4.1.7.5.3 *Radiological Health Impacts to the Public for All Phases*

Table 4-34 lists the estimated dose and radiological health impacts to the public for all phases. It lists dose and the potential radiological impact to the offsite maximally exposed individual for a 70-year lifetime with continuous residency about 20 kilometers (12 miles) south of the repository, and collective dose and potential radiological health impacts to the population within about 80 kilometers (50 miles) for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively.

Table 4-34. Estimated dose and radiological impacts to the public for all phases.[a,b]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] (millirem)	38	46	100
Latent cancer fatality probability	1.9×10^{-5}	2.3×10^{-5}	5.1×10^{-5}
Collective dose[d] (person-rem)	280	340	810
Latent cancer fatality incidence	0.14	0.17	0.41

a. Source: Tables 4-22, 4-28, and 4-31.

b. Values are rounded to two significant figures.

c. Dose over a 70-year lifetime of the operation and monitoring phase, with continuous residency about 20 kilometers (12 miles) south of the repository.

d. Over all phases, lasting a total of 110, 111, or 120 years for the high, intermediate, or low thermal load scenario, respectively.

The offsite maximally exposed individual would have an increase in the probability of incurring a latent cancer fatality ranging from about 0.00002 to 0.00005 from exposure to radionuclides released from the repository facilities over a 70-year lifetime. The total estimated number of latent cancer fatalities in the potentially exposed population would range from 0.14 to 0.41 for the three thermal load scenarios. All doses and estimated radiological impacts would be from exposure to naturally occurring radon-222 and its decay products released from the subsurface facilities in exhaust ventilation air.

For comparison, the average individual radiation doses from natural sources of background radiation for Amargosa Valley and for the population of the United States are about 340 and 300 millirem per year, respectively (see Chapter 3, Table 3-28). Over a 70-year lifetime, individual dose from background radiation would be about 25,000 millirem, which is about 250 times larger than the offsite maximally exposed individual dose listed in Table 4-34. The highest annual dose to a member of the public from repository sources would be about 1.5 millirem or less. This radiation dose, essentially all from naturally occurring radon-222 and decay products, would be about 0.7 percent of the 200-millirem-per-year dose from radon-222 to members of the public in Amargosa Valley from ambient levels of naturally occurring radon (see Chapter 3, Section 3.1.8.2).

The Nevada cancer fatality rate in a population of 100,000 males is about 163 deaths per year (ACS 1998, page 6). Assuming this mortality rate is a baseline that would remain unchanged for the estimated population (in 2000) of about 28,000 within about 80 kilometers (50 miles) of the Yucca Mountain site, there would be about 50 cancer deaths per year from other causes and more than 5,000 cancer deaths over the period of the repository phases. The impact calculations in this EIS indicate that the additional

cancer fatalities for the public from short-term activities would be less than 0.4, which would be an increase of about 0.01 percent.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual,* defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker,* a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

> **ACCIDENT TYPES**
>
> **Radiological accidents** are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.
>
> **Nonradiological accidents** are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The impacts to offsite individuals from repository accidents would be small, with calculated doses as high as 0.013 rem to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher, bounded by the worst-case accident scenarios at 31 rem.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accident s. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide source term for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix H contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a typical fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur

- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs

- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be about 11 kilometers (about 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the frequency of wind in each direction enters the continuous release calculation of the maximally exposed individual.

- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Sixteen accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, fuel canisters, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

Table 4-35 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-36 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from

Table 4-35. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	1.9×10^{-3}	1.0×10^{-6}	5.5×10^{-2}	2.7×10^{-5}	9.4×10^{-1}	3.8×10^{-4}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	2.3×10^{-3}	1.2×10^{-6}	6.6×10^{-2}	3.3×10^{-5}	1.1	4.4×10^{-4}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies- no filtration	1.4×10^{-3}	1.3×10^{-3}	6.5×10^{-7}	3.9×10^{-2}	2.0×10^{-5}	5.7×10^{-1}	2.3×10^{-4}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	1.4×10^{-3}	7.0×10^{-7}	4.6×10^{-2}	2.3×10^{-5}	6.6×10^{-1}	2.6×10^{-4}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	3.7×10^{-7}	1.9×10^{-10}	1.1×10^{-5}	5.3×10^{-9}	1.1×10^{-4}	4.4×10^{-8}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	1.2×10^{-3}	6.0×10^{-7}	3.4×10^{-2}	1.7×10^{-5}	3.6×10^{-1}	1.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	6.6×10^{-7}	3.3×10^{-10}	4.0×10^{-4}	2.0×10^{-7}	1.7×10^{-4}	6.8×10^{-8}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	5.6×10^{-4}	2.8×10^{-7}	1.7×10^{-2}	8.6×10^{-6}	1.6×10^{-1}	6.4×10^{-5}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	5.1×10^{-7}	2.6×10^{-10}	2.9×10^{-4}	1.5×10^{-7}	1.3×10^{-4}	5.2×10^{-8}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	6.1×10^{-4}	3.1×10^{-7}	1.6×10^{-2}	8.2×10^{-6}	1.8×10^{-1}	7.2×10^{-5}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	1.8×10^{-6}	9.0×10^{-10}	1.0×10^{-3}	5.2×10^{-7}	5.0×10^{-4}	2.0×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	1.7×10^{-3}	8.5×10^{-7}	5.1×10^{-2}	2.5×10^{-5}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	1.1×10^{-1}	5.4×10^{-5}	1.5	6.0×10^{-4}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	9.1×10^{-3}	4.6×10^{-6}	3.6×10^{-1}	1.8×10^{-4}	8.3	3.3×10^{-3}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-5}	1.8×10^{-5}	9.0×10^{-9}	6.3×10^{-4}	3.2×10^{-7}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	6.1×10^{-10}	3.1×10^{-13}	2.1×10^{-8}	1.1×10^{-11}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer/Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

Table 4-36. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	7.2×10^{-3}	3.5×10^{-6}	1.7	8.6×10^{-4}	5.1	2.0×10^{-3}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	8.0×10^{-3}	4.0×10^{-6}	2.1	1.1×10^{-3}	5.9	2.4×10^{-3}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	1.4×10^{-3}	4.3×10^{-3}	2.2×10^{-6}	1.3	6.5×10^{-4}	3.1	1.2×10^{-3}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	5.2×10^{-3}	2.6×10^{-6}	1.5	7.8×10^{-4}	3.5	1.4×10^{-3}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	1.2×10^{-6}	6.0×10^{-10}	2.6×10^{-4}	1.3×10^{-7}	3.3×10^{-4}	1.3×10^{-7}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	8.6×10^{-1}	4.3×10^{-4}	1.1	4.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	2.5×10^{-6}	1.3×10^{-9}	3.3×10^{-2}	1.6×10^{-5}	4.6×10^{-4}	1.8×10^{-7}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	2.1×10^{-3}	1.1×10^{-6}	5.6×10^{-1}	2.8×10^{-4}	4.6×10^{-1}	1.8×10^{-4}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	2.1×10^{-6}	1.1×10^{-9}	2.4×10^{-2}	1.2×10^{-5}	3.8×10^{-4}	1.5×10^{-7}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	2.2×10^{-3}	1.1×10^{-6}	5.1×10^{-1}	2.6×10^{-4}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	7.3×10^{-6}	3.7×10^{-9}	8.6×10^{-2}	4.3×10^{-5}	1.3×10^{-3}	5.2×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	6.1×10^{-3}	3.1×10^{-6}	1.6	8.0×10^{-4}	1.3	5.2×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	1.3×10^{-2}	6.5×10^{-6}	3.2	1.6×10^{-3}	3.9	1.6×10^{-3}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	3.2×10^{-2}	1.6×10^{-5}	14	7.2×10^{-3}	7.0	2.8×10^{-2}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-4}	5.8×10^{-5}	2.9×10^{-8}	2.1	1.1×10^{-5}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	1.9×10^{-9}	9.5×10^{-13}	7.5×10^{-7}	3.7×10^{-10}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection, as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident since operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

The most severe accident scenario (earthquake, Table 4-36, number 14) for the 95-percent weather conditions would result in an estimated 0.0072 additional latent cancer fatality for the same affected population. The more conservative summation of all potential accidents in Table 4-36 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the individual receptors from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. As noted in Chapter 2, this EIS evaluates other packaging scenarios that include commercial spent nuclear fuel that would arrive at the repository in canisters suitable for disposal without being opened. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, thus provides a bounding assessment of accident impacts for the packaging scenarios considered in Chapter 2 because accident scenarios involving damage to bare fuel assemblies during handling operations represent the bounding repository accident scenarios. The uncanistered fuel, as indicated in Tables 4-35 and 4-36, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

The analysis evaluated accident scenario impacts during retrieval, and concluded that the transporter runaway and derailment accident scenarios evaluated for emplacement operation would bound other accident scenarios during retrieval operations that are credible. This conclusion is supported by the results of accident evaluations for above-ground dry storage at utility sites, as discussed in Appendix H.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that

any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

The accident analysis separately considered sabotage as a potential initiating event. This event would be unlikely to contribute to impacts from the repository. The repository would not represent an attractive target to potential saboteurs due to its remote location and the low population density in the area. Furthermore, security measures DOE would use to protect the waste material from intrusion and sabotage (TRW 1999a, pages 63 to 65) would make such attempts unlikely to succeed. At all times the waste material would be either in robust shipping or disposal containers or inside the Waste Handling Building, which would have thick concrete walls. On the basis of these considerations, DOE concluded that sabotage events would be unlikely at the repository.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in large impacts. Because performance confirmation activities would be similar to those for site characterization, large impacts would be likely.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal, South Portal, and Ventilation Shaft Operations Areas involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (TRW 1997c, page 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Operations Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DOE 1997k, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the analyzed land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical receptor at the analyzed land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Lathrop Wells, about 22 kilometers (14 miles) from the repository site], DOE expects no large noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all repository phases would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no large noise impacts to the public and workers.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and the visibility of the repository site from publicly accessible locations is low or nonexistent. The largest structure would be the Waste Handling Building at the North Portal Operations Area, which would be about 37 meters (120 feet) tall with a taller exhaust stack. Other buildings and structures would be smaller and at elevations equal to or lower than that of the Waste Handling Building. No building or structure would exceed the elevation of the southern ridge of Yucca Mountain [1,400 meters (4,600 feet)]. Therefore, no part of the repository would be visible to the public from the west. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near Lathrop Wells and the Amargosa Valley, approximately 28 kilometers (17 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points.

Closure activities, such as dismantling facilities and reclaiming the site, probably would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. The scope of the analysis included electric power use, fossil-fuel consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-37 lists electric energy and fossil-fuel use during the different phases. Table 4-38 lists construction material use. Both tables list comparative values for all thermal load and packaging scenarios. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE does not expect meaningful impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Performance Confirmation

DOE would obtain utilities, energy, and materials for performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, performance confirmation activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 3,700 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.3 percent of the 1997 population (see Chapter 3, Section 3.1.7.1). This increase would be a smaller portion of the county's population in 2030 and, correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark

Table 4-37. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load UC[c]	High thermal load DISP[d]	High thermal load DPC[e]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
Peak electrical power demand (megawatts)										
Construction	2005-2010	24	24	24	24	24	24	24	24	24
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	19	19	19	19	19	19
Emplacement	2010-2033	22	18	19	22	18	19	22	18	19
Total development and emplacement	*2010-2033*	*41*	*38*	*38*	*41*	*38*	*38*	*41*	*38*	*38*
Decontamination	2034-2037	14	10	11	14	10	11	14	10	11
Monitoring	2034-2110	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2060	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2310	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Closure	2110+6-15	9.2	8.9	8.9	9.2	8.9	8.9	9.2	8.9	8.9
Electricity use (1,000 megawatt-hours)										
Construction	2005-2010	180	180	180	230	230	230	240	240	240
Operation and monitoring	2010-2110									
Development	2010-2032	650	650	650	890	890	890	2,200	2,200	2,200
Emplacement	2010-2033	2,600	2,100	2,100	2,600	2,100	2,100	2,600	2,100	2,200
Decontamination	2034-2037	250	190	200	250	190	200	250	190	200
Monitoring	2034-2110	2,000	2,000	2,000	2,400	2,400	2,400	3,500	3,500	3,500
	2034-2060	680	680	680	810	810	810	1,200	1,200	1,200
	2034-2310	7,200	7,200	7,200	8,600	8,600	8,600	13,000	13,000	13,000
Total 100-year phase	*2010-2110*	*5,500*	*4,900*	*5,000*	*6,100*	*5,600*	*5,600*	*8,600*	*8,000*	*8,100*
Closure	2110+6-15	250	240	240	370	370	370	560	560	560
Fossil-fuel use (million liters)[f]										
Construction	2005-2010	8.1	7.1	7.3	12	11	12	14	13	13
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	20	20	20	83	83	85
Emplacement	2010-2033	230	180	190	230	180	190	230	180	190
Decontamination	2034-2037	33	26	27	33	26	27	33	26	27
Monitoring	2034-2110	11	11	11	15	15	15	15	15	15
	2034-2060	3.9	3.9	3.9	5.0	5.0	5.0	5.0	5.0	5.0
	2034-2310	41	41	41	53	53	53	53	53	53
Total 100-year phase	*2010-2110*	*290*	*240*	*240*	*290*	*250*	*250*	*360*	*310*	*310*
Closure	2110+6-15	5.1	4.5	4.6	9.4	8.8	8.9	15	14	15

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-17 to 6-24).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert liters to gallons, multiply by 0.26418.

Table 4-38. Construction material use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load UC[c]	High thermal load DISP[d]	High thermal load DPC[e]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
Concrete (1,000 cubic meters)[f]										
Construction	2005-2010	330	330	330	390	380	380	390	390	390
Operation and monitoring	2010-2110									
Development	2010-2032	420	420	420	480	480	480	1,700	1,700	1,700
Emplacement	2010-2033	27	27	27	27	27	27	66	66	66
Operation and monitoring total	*2010-2110*	*450*	*450*	*450*	*510*	*510*	*510*	*1,800*	*1,800*	*1,800*
Closure	2110+6-15	2	2	2	2	2	2	4	4	4
Project total		*780*	*780*	*780*	*900*	*890*	*890*	*2,200*	*2,200*	*2,200*
Steel (1,000 metric tons)[g]										
Construction	2005-2010	70	68	67	81	81	81	83	81	80
Operation and monitoring	2010-2034									
Development	2010-2032	90	90	90	140	140	140	610	610	610
Emplacement	2010-2033	42	42	42	42	42	42	110	110	110
Operation and monitoring total	*2010-2110*	*130*	*130*	*130*	*180*	*180*	*180*	*720*	*720*	*720*
Closure	2110+6-15	0.71	0.71	0.71	0.92	0.92	0.92	2	2	2
Project total		*200*	*200*	*200*	*260*	*260*	*260*	*800*	*800*	*800*
Copper (1,000 metric tons)										
Construction	2005-2010	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operation and monitoring	2010-2110									
Development	2010-2032	0.1	0.1	0.1	0.1	0.1	0.1	0.9	0.9	0.9
Project total		*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*1.0*	*1.0*	*1.0*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-15 to 6-21).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert cubic meters to cubic yards, multiply by 1.3079.
g. To convert metric tons to tons, multiply by 1.1023

County would increase by a projected maximum of about 110 as a result of the Proposed Action. This number represents about 10 percent of the 1997 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (SNWA 1999, all), would require a quantity of water that is about 6 percent of the community's quasimunicipal groundwater withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (Horton 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.20 million cubic meters (160 acre-feet) of water per year. This represents about 0.2 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.18 million cubic meters (150 acre-feet) to Pahrump's annual water demand, which represents about 0.6 percent of the 1995 Pahrump water withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.3 percent of the 1997 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase (2005 to 2010), the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electrical power during the construction phase would be about 24 megawatts with use varying between about 180,000 and 240,000 megawatt-hours, depending on the thermal load scenario and the packaging scenario. Excavation activities for all three thermal load scenarios would use two or three tunnel boring machines. However, the operations time would increase for the low thermal load scenario because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below.

During the early stages of the operation and monitoring phase (2010 to 2033), the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 38 and 41 megawatts, depending on the thermal load scenario and the packaging scenario.

Following the completion of excavation activities in about 2032, the demand for electric power would drop to about 20 megawatts and would continue to drop, following the completion of emplacement and decontamination activities in about 2037, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 6 to 15 years, depending on the thermal load scenario. The peak electric power demand would be less than 10 megawatts for any of the three thermal load scenarios during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (*Las Vegas Review-Journal* 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (NPC 1997, Figures 2 and 4). The maximum 41-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 6 percent of the planned reserve. Thus, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric supply capacity to the site after construction began in 2005. DOE would have to increase the electric power supply to the site to accommodate the initial demand of about 24 megawatts during the construction phase and to support the estimated peak demand of as much as 41 megawatts during the operation and monitoring phase. A range of options focusing on a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (TRW 1998e, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation, and increasing the capacity of the steam plant would not be cost-effective with the availability of low-priced power in the southern Nevada region. Limited onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 50 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with the projected repository load (as much as 41 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Lathrop Wells. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered adding Sierra Pacific Power Corporation as a supplier by constructing a new power line from the Tonopah/Anaconda area to Lathrop Wells through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, additional National Environmental Policy Act analysis could be required.

Fossil Fuels

Fossil fuels used during the construction phase (2005 to 2010) would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. In addition, fuel oil would provide water heating and building heat to the South Portal and heat for curing precast concrete components. During construction the estimated use of diesel fuel and fuel oil would be 7.1 million to 14 million liters (1.9 million to 4 million gallons). The highest use would be associated with the combination of the low thermal load scenario and the uncanistered packaging scenario. The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (BTS 1999a, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 240 million and 360 million liters (about 63 million and 95 million gallons) depending on the thermal load scenario and the packaging scenario. The annual use would be highest for emplacement and development operations (2010 to 2033) and would decrease substantially for monitoring and maintenance activities (2034 to 2110). The projected use of liquid fossil fuels would be within the regional supply capacity and should not cause meaningful impacts. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (BTS 1999a, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations and monitoring phase would be less than 5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 4.5 million and 15 million liters (1.2 million and 4 million gallons), depending on the thermal load scenario. Use during the closure phase would be similar to that for the construction phase.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners in the subsurface and for the construction of the surface facilities. Excavated rock would be used for the aggregate, and cement would be purchased regionally. During the construction phase the amount of concrete required would range

from about 330,000 to 390,000 cubic meters (about 430,000 to 510,000 cubic yards), depending on the thermal load scenario and the packaging scenario. For this phase, as much as about 83,000 metric tons (92,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 100 metric tons (110 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ substantially for the high, intermediate, and low thermal load scenarios, the relative amount of material used during the initial 5-year construction period might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for each of the intermediate thermal load cases would be about the same as the amount for the corresponding low thermal load case, but the total amount of steel used for each intermediate case through the completion of development would be about one-quarter of the amount that would be used for the corresponding low thermal load case.

During the operation and monitoring phase, an additional 1.8 million cubic meters (2.4 million cubic yards) of concrete would be required for the low thermal load scenario and 450,000 cubic meters (590,000 cubic yards) would be required for the high thermal load scenario. The corresponding requirement for steel would be between about 720,000 and 130,000 metric tons (about 790,000 and 140,000 tons), and for copper it would be about 100 metric tons (110 tons).

For the low thermal load scenario, which would require the most concrete, the average yearly concrete demand for continued subsurface development during the operation and monitoring phase would be about 82,000 cubic meters (about 110,000 cubic yards). This quantity of concrete represents less than 3 percent of the cement consumed in Nevada in 1998 (Sherwood 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 4,000 cubic meters (5,200 cubic yards) of concrete for the low thermal load option. An estimated 2,000 metric tons (2,200 tons) of steel would be required for the low thermal load scenario and about 710 metric tons (780 tons) for the high thermal load scenario.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security

officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, no meaningful impact to the emergency facilities of surrounding communities or counties would be likely.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes. The overall impact of managing the Yucca Mountain repository waste streams would not differ among the thermal load scenarios and packaging scenarios. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. The Proposed Action would not cause meaningful impacts at offsite facilities for low-level radioactive and hazardous waste disposal. DOE would use less than 3 percent of the existing offsite capacity for low-level radioactive waste disposal and a very small fraction of the existing hazardous waste disposal capacity. In addition, the Department would build an onsite landfill. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lives of 70 and 100 years (DOE 1995f, pages 8 and 9) and probably would require the expansion of their capacities. Further review under the National Environmental Policy Act might be required to expand the capacity of the landfills at the Nevada Test Site.

4.1.12.1 Waste and Materials Impacts from Performance Confirmation

DOE expects performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal qualities (TRW 1999a, page 17). Based on 1997 waste generation reports, performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (Sygitowicz 1998, pages 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (Harris 1998, pages 3-6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

sanitary sewage. Based on site characterization experience, performance confirmation activities would cause no meaningful impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase (2005 to 2010) would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-39 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and

Table 4-39. Estimated waste quantities from construction.[a]

	High thermal load			Intermediate thermal load			Low thermal load		
Waste type	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction debris (cubic meters)[e]	3,000	2,400	2,400	3,000	2,400	2,400	3,000	2,400	2,400
Hazardous (cubic meters)	990	690	740	990	690	740	990	690	740
Sanitary and industrial solid (cubic meters)	10,000	8,500	8,700	10,000	8,500	8,700	10,000	8,500	8,700
Sanitary sewage (million liters)[f]	160	150	150	160	160	160	160	160	160
Industrial wastewater (million liters)	42	42	42	51	51	51	51	51	51

a. Sources: TRW (1999a, page 66); TRW (1999b, pages 6-8 and 6-9).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

sanitary and industrial solid waste. The capacity of this landfill would be large enough to dispose of the projected volumes of this debris and waste for the entire Proposed Action. As listed in Table 4-39, DOE estimates a maximum of 3,000 cubic meters (110,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 10C landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37). The disposal of construction debris generated during the construction phase would consume less than one-half of 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37). The disposal of the maximum of 10,000 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use about 2 percent of the disposal capacity.

Table 4-40 lists the estimated total waste quantities for repository activities associated with emplacement and development (2010 to 2033). Major waste-generating activities would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. The thermal load scenarios would cause differences in nonradioactive waste quantities from subsurface activities due to the different workforce sizes and main drift lengths. The three packaging scenarios would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. The dual-purpose canister packaging scenario could require the disposal of an additional estimated 44,000 cubic meters (1.6 million cubic feet) of low-level radioactive waste (not listed in Table 4-40) with an estimated weight of 240,000 metric tons (270,000 tons) (Koppenaal 1998a, all; TRW 1999a, page 75). DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. As listed in Table 4-39, DOE estimates the generation of no more than 990 cubic meters (35,000 cubic feet)

Table 4-40. Estimated waste quantities from emplacement and development activities (2010 to 2033).[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Hazardous (cubic meters)[e]	5,800	2,300	2,200	5,800	2,300	2,200	5,800	2,300	2,200
Sanitary and industrial solid (cubic meters)	50,000	41,000	42,000	50,000	41,000	42,000	70,000	61,000	62,000
Sanitary sewage (million liters)[f]	1,400	1,100	1,200	1,400	1,100	1,100	1,400	1,200	1,200
Industrial wastewater (million liters)	900	780	780	930	810	810	1,400	1,300	1,300
Low-level radioactive (cubic meters, after treatment)	67,000	18,000	26,000	67,000	18,000	26,000	67,000	18,000	26,000

a. Sources: TRW (1999a, pages 75 and 76); TRW (1999b, pages 6-17, 6-18, and 6-23).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

of hazardous waste during the construction phase. This maximum volume would result from the construction of facilities to accommodate the uncanistered packaging scenario. The Environmental Protection Agency's National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 1993 to 2013 capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states (including Nevada and other states to which repository waste could be shipped for treatment and disposal) is about seven times more than the demand for these services. The landfill capacity would be about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of hazardous waste from the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Operations Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Operations Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (TRW 1998g, pages 65 to 67). The accumulated sludge at the South Portal Operations Area evaporation pond, which would consist of mined rock, Portland Cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (Koppenaal 1998b, page 3).

During the operation and monitoring phase (2010 to 2110), the receipt and packaging of spent nuclear fuel and high-level radioactive waste, the operation of support facilities, and the continued development of subsurface emplacement areas would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would also have the capability to package and temporarily store mixed waste that operations could generate in unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that would be disposed of in accordance with applicable Federal and State of Nevada requirements.

Monitoring and maintenance activities after the completion of emplacement (2034 to 2110) would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 520 cubic meters (18,000 cubic feet) of low-level

radioactive waste and as much as 260 cubic meters (9,200 cubic feet) of hazardous waste from this activity (TRW 1999a, page 78), depending on the packaging scenario.

Monitoring and maintenance activities over 26 years would generate a maximum of about 9,900 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste and about 230 million liters (60 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 76 years would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 450 million liters (120 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 276 years (closure 300 years after the start of emplacement) would generate a maximum of about 61,000 cubic meters (about 2.2 million cubic feet) of sanitary and industrial solid waste and about 1.3 billion liters (340 million gallons) of sanitary sewage (TRW 1999a, page 85; TRW 1999b, pages 6-28 and 6-29).

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DOE 1995f, page 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1). After treatment, DOE would need to dispose of an estimated maximum 68,000 cubic meters (2.4 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities (TRW 1999a, pages 72 and 78). This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated disposal capacity of 3.15 million cubic meters (110 million cubic feet) (DOE 1998l, page 2-19) (see Section 3.1.12). The impact to the total capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 2.2 percent.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,100 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities (TRW 1999a, pages 72 and 78). The estimated maximum annual rate of hazardous waste treatment or disposal would be 260 cubic meters (9,200 cubic feet) (TRW 1999a, page 78). At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year available capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states is about seven times more than the demand for these services. The estimated landfill capacity is about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1 cubic meter (35 cubic feet) (TRW 1999a, page 74), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for

the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal (DOE 1996f, page 4-36). This facility has a planned annual capacity of 13,000 cubic meters (460,000 cubic feet) (DOE 1997b, Volume 1, page 6-6).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-41 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure with the low thermal load scenario and differences in surface facilities for the packaging scenarios.

Table 4-41. Estimated waste quantities from closure.[a]

Waste type	Quantity
Demolition debris (cubic meters)[b]	100,000 - 150,000
Hazardous (cubic meters)	440 - 630
Sanitary and industrial (cubic meters)	4,400 - 10,000
Sanitary sewage (million liters)[c]	83 - 200
Industrial wastewater (million liters)	42 - 105
Low-level radioactive (cubic meters, after treatment)	2,100 - 3,500

a. Sources: TRW (1999a, page 81); TRW (1999b, pages 6-38 and 6-39).
b. To convert cubic meters to cubic feet, multiply by 35.314.
c. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The 10C landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DOE 1995f, pages 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity and would ship low-level radioactive waste to a Nevada Test Site disposal facility. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the disposal capacity about one-tenth of 1 percent.

Table 4-42 lists the waste types that repository activities would generate from construction through closure and the total estimated waste quantities for the nine thermal load scenario and packaging combinations. The table summarizes waste quantities for all phases of the Proposed Action.

If not recycled, dual-purpose canisters would add an estimated 44,000 cubic meters (1.6 million cubic feet) of low-level waste under each of the dual-purpose canister packaging scenarios (Koppenaal 1998a, all; TRW 1999a, page 76).

Table 4-42. Estimated waste quantities for Proposed Action.[a]

	High thermal load			Intermediate thermal load			Low thermal load		
Waste type	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction and demolition debris (cubic meters)[e]	150,000	100,000	120,000	150,000	100,000	120,000	150,000	100,000	120,000
Hazardous (cubic meters)	7,700	3,500	3,500	7,700	3,500	3,500	7,700	3,500	3,500
Sanitary and industrial solid (cubic meters)	85,000	73,000	74,000	85,000	73,000	74,000	110,000	98,000	99,000
Sanitary sewage (million liters)[f]	2,000	1,800	1,800	2,000	1,800	1,800	2,200	1,900	2,000
Industrial wastewater (million liters)	980	870	870	1,000	900	900	1,600	1,500	1,500
Low-level radioactive (cubic meters after treatment)	71,000	21,000	29,000	71,000	21,000	29,000	71,000	21,000	29,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.2641.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DOE 1996h, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (TRW 1999a, page 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DOE 1997h, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-43 lists estimated quantities of materials that DOE would recycle during the life of the repository.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DOE 1997l, page 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (TRW 1999a, page 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could

Table 4-43. Estimated recyclable material quantities.[a]

Material	UC[b]	DISP[c]	DPC[d]
High thermal load			
Recyclables (cubic meters)[e,f]	210,000	170,000	180,000
Steel (metric tons)[g]	37,000	27,000	31,000
Dual-purpose canisters[h] (cubic meters)	NA[i]	NA	44,000
Oils and lubricants (liters)[j]	28,000,000	28,000,000	28,000,000
Intermediate thermal load			
Recyclables (cubic meters)	210,000	170,000	180,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	39,000,000	39,000,000	39,000,000
Low thermal load			
Recyclables (cubic meters)	260,000	230,000	240,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	63,000,000	63,000,000	63,000,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
f. To convert cubic meters to cubic feet, multiply by 35.314.
g. To convert metric tons to tons, multiply by 1.1023.
h. Dual-purpose canisters would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 220,000 metric tons.
i. NA = not applicable.
j. To convert liters to gallons, multiply by 0.26418.

lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines to determine if disproportionately high and adverse impacts to human health or the environment on minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

The environmental justice analysis brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. If any of these analyses were to predict high and adverse impacts to the human population in general, then an environmental justice analysis would determine if those impacts could occur in a disproportionately high and adverse manner to minority or low-income populations. The basis for making this determination is a comparison of the areas of large impacts with maps that indicate high percentages of minority or low-income populations as reported by the Bureau of the Census.

The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (CEQ 1997, all).

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (CEQ 1997, all)]. Nevada has a minority population of 21 percent (Bureau of the Census 1992a, Tables P8 and P12). For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 31 percent or higher.

Nevada has a low-income population of 10 percent. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (OMB 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

The environmental justice analysis involves a two-stage assessment of the potential for disproportionately high and adverse impacts on minority and low-income populations:

- First, a review of the activities included in the Proposed Action to determine if they are likely to result in any high and adverse human health impacts

- Second, if the first-stage review identified any high and adverse impacts to human populations in general, an analysis of whether minority or low-income populations would be affected disproportionately

The EIS analyses determined that the impacts that could occur to public health and safety would be small on the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionate impacts.

4.1.13.2 Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American groups to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

DOE has identified potential impacts to public health and safety from repository construction and operation (Section 4.1.7). However, DOE expects such impacts to be small. Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction of site access. There are no communities with high percentages of minority or low-income populations near the proposed repository site.

Socioeconomics

Because of the large population and workforce in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, the regional workforce would increase less than 0.5 percent above the baseline level (see Section 4.1.6). Changes to the baseline regional population would not be greater than 0.5 percent for the duration of the entire project. Because the Proposed Action would generate minimal impacts to employment and population, potential socioeconomic impacts would be small.

DOE would continue its Native American Interaction Program to help manage cultural resources during construction and operation.

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.9. Those sections address impacts from all phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income

populations, that would receive disproportionate impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (AIWS 1998, page 2-1), that the lands around the site contain cultural, animal, and plant resources important to those tribes, and that the implementation of the Proposed Action would continue restrictions on free access to the repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *...we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (AIWS 1998, page 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (AIWS 1998, page 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (AIWS 1998, page 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (AIWS 1998, page 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (AIWS 1998, page 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (AIWS 1998, page 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (AIWS 1998, page 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native Americans.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *...health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (AIWS 1998, page 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (AIWS 1998, page 2-19).*

DOE recognizes that Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will consult with tribal governments and will work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that could affect tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

4.1.14 IMPACTS OF THERMAL LOAD AND PACKAGING SCENARIOS

This section summarizes and compares the short-term environmental impacts for the three thermal load scenarios. These scenarios for the repository are high thermal load (85 MTHM per acre), intermediate thermal load (60 MTHM per acre) and low thermal load (25 MTHM per acre).

Overall the EIS analysis found that differences in environmental impacts for the three thermal load scenarios would be low and that the differences between the scenarios would be small. More specifically:

- All of the short-term impacts from repository activities would be small, both to workers and to the public.

- Long-term impacts to the public for the three thermal load scenarios would be essentially the same for collective dose and for latent cancer fatalities. They would be low (0.005 to 0.02 latent cancer fatality). Over the first 10,000 years, the risk of a latent cancer fatality to the maximally exposed individual would also be low (from 0.000001 to 0.000003) at 20 kilometers (about 12 miles) downgradient from Yucca Mountain. Individual dose rates would be highest for the high thermal load scenario and lowest for the low thermal load scenario.

- Short-term impacts for the surface-water, biological and soil, cultural, aesthetics, noise, and environmental justice resource areas would be small regardless of the thermal load scenario.

Short-term environmental impacts for activities at the repository as a function of packaging scenarios include:

- The greatest impacts for repository-related activities would be associated with the uncanistered packaging scenario with the exception of the generated volumes of solid and industrial wastes. For these wastes, the greatest impacts would result from the dual-purpose and disposable shipping packaging scenarios because these two types of shipping package would eventually become waste.

- Differences in impacts among the packaging scenarios would not be large, generally between 10 and 20 percent.

4.1.15 IMPACTS FROM MANUFACTURING DISPOSAL CONTAINERS AND SHIPPING CASKS

This section discusses the potential environmental impacts from the manufacturing of disposal containers and shipping casks required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (USN 1996a, all). DOE's evaluation focuses on ways in which the manufacture of the disposal containers and shipping casks could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture disposal containers and shipping casks is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (USN 1996a, page 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (USN

1996a, page 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers and shipping casks for the Yucca Mountain Repository. Therefore, the analysis considered the manufacturing processes used at these facilities and the total number of disposal containers and shipping casks required to implement each packaging scenario. The analysis assumed that the manufacture of disposal containers and shipping casks would occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of disposal container and cask manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the disposal containers and shipping casks. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-44 lists the quantities of disposal containers and shipping casks analyzed for the packaging scenarios described in Chapter 2. Table 4-44 includes disposal containers for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. USN (1996a, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel represents less than 4 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would not add much to the impacts described in the following sections.

Table 4-44. Quantities of disposal containers and shipping casks for the Yucca Mountain Repository.[a]

Component	Description	Packaging scenario[b] UC	DISP	DPC
Disposal containers[c]	Containers for disposal of SNF and HLW[d]	10,200	11,400	10,200
Rail shipping casks or overpacks[f]	Storage and shipment of SNF and HLW	0	100	110
Legal-weight truck shipping casks[f]	Storage and shipment of uncanistered fuel	120	10	10

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: TRW (1999c, Section 6); values have been rounded.
d. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
e. A larger number of disposal containers is required for disposable canisters because they cannot be packed as densely as other canisters.
f. Cask fleet developed from Ross (1998, all); JAI (1996, all); TRW (1998j, Table 12, pages 17 and 18).

As currently planned, all of the components listed in Table 4-44 would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of A 516 carbon steel that would be 100 millimeters (3.9 inches) thick and an inner liner of corrosion-resistant high-nickel alloy (C-22) that would be 20 millimeters (0.8 inch) thick (TRW 1999c, Section 6.0, page 6-1). The flat end pieces would be 110-millimeter (4.3-inch)-thick carbon steel and 25-millimeter (1-inch)-thick high-nickel alloy. The bottom end pieces would be welded to the cylindrical body at the fabrication shop, and the top end pieces would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 16 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.8 to 6.2 meters (12 to 20 feet) and the outside diameters would range from 1.3 to 2 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 21 to 38 metric tons (23 to 42 tons) (TRW 1999c, Section 4.0, pages 4-16 to 4-21).

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (USN 1996a, pages 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Rail casks presently used to ship naval spent nuclear fuel are shorter and are designed to sit upright on railcars. Empty truck casks typically weigh from 21 to 2 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (JAI 1996, all).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for

the manufacture of disposal containers and shipping casks. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because existing facilities could accommodate the manufacture of disposal containers and shipping casks and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of disposal containers and shipping casks would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990, the latest year for which county-level data are available (USN 1996a, page 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the last year for which statistics are available, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (USN 1996a, page 4-5).

The manufacture of hardware for each of the packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required disposal containers and shipping casks for nuclear materials. Machining operations at these facilities would involve standard procedures using established metal-working equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area. The counties comprising each Metropolitan Statistical Area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 430,000 to 970,000 in 1992 (USN 1996a, page 4-6). In 1995 output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion, income (wages, salaries, and property income) ranged from $9 billion to $26 billion, employment ranged from 245,000 to 670,000 in 1995, and plant employment ranged from 25 to 995 (USN 1996a, page 4-6). Based on averages of this information, the representative manufacturing location has a population of about 640,000 and the facility employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. In addition, this section contains a qualitative discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in USN (1996a, Section 4.3) to estimate air emissions from manufacturing sites for the production of disposal containers and shipping casks. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of disposal containers and shipping casks were developed using the emissions resulting from manufacturing similar components (USN 1996a, page 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of disposal containers and shipping casks manufactured over 24 years for each packaging scenario.

Table 4-45 lists the estimated annual average and estimated total 24-year emissions from the manufacture of disposal containers and shipping casks at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 0.58 to 0.61 metric ton (approximately 0.64 to 0.67 ton) a year. Nitrous oxides would be the largest emission, varying from 0.75 to 0.78 metric ton (approximately 0.83 to 0.86 ton) a year for the packaging scenarios. Annual

Table 4-45. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location for the different packaging scenarios.

Compound	Measure	Packaging scenario[b]		
		UC	DISP	DPC
Volatile organic compounds	Annual average	0.60	0.61	0.58
	24-year total	15	15	14
	Percent of *de minimis*[c]	6.6%	6.7%	6.4%
Nitrogen oxides	Annual average	0.78	0.78	0.75
	24-year total	19	19	18
	Percent of *de minimis*[c]	8.6%	8.6%	8.2%

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).

average emissions from disposal container and shipping cask manufacturing under any of the scenarios would be less than 0.02 percent of regional emissions of volatile organic compounds and 0.002 percent of regional emissions of nitrous oxides. Emissions from the manufacture of disposal containers and shipping casks would contain a relatively small amount of ozone precursors compared to other sources.

The examination of the packaging scenarios assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-45 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of disposal containers and shipping casks in relation to the emission threshold level of an extreme ozone nonattainment area. Air emissions from the manufacture of disposal containers and shipping casks would vary depending on the packaging scenario, with ranges of 6.4 to 6.7 percent and 8.2 to 8.6 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 10 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to disposal containers and shipping casks (USN 1996a, page 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-46 lists the expected number of injuries and illnesses and fatalities for each packaging scenario based on the work years required to produce the number of disposal containers and shipping casks needed over 24 years. Injuries and illnesses would range from 265 to 276. Fatalities would be unlikely.

Table 4-46. Injuries, illnesses, and fatalities over 24 years at the representative manufacturing location for the packaging scenarios.

Parameter	Packaging scenario[a] UC	DISP	DPC
Injuries and illnesses	275	276	265
Fatalities	0.13	0.13	0.13

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of disposal containers and shipping casks would not place unusual demands on existing manufacturing facilities. Thus, none of the packaging scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers (TRW 1999c, Sections 5 and 6) and per-unit cost of shipping casks (TRW 1998j, Table 12, pages 17 and 18)

- Total number of disposal containers and shipping casks to be manufactured (TRW 1999c, Section 6)

- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of disposal container and shipping cask manufacturing on the local economy (BEA 1992, all)

  Direct effects would occur as manufacturing facilities purchased materials, services, and labor required for manufacturing.

  Secondary effects would occur as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-47 lists the state-specific multipliers and the composite multipliers.

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of disposal containers and shipping casks probably

Table 4-47. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($)		Direct effect multiplier (number of jobs)
	Products	Earnings	
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: Bureau of the Census (1992h, all).

would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under a packaging scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 1998 dollars. No attempt was made to forecast local economic growth or inflation rates for the representative location because of the non-site-specific nature of the analysis.

Table 4-48 lists the impacts of each packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Table 4-48. Socioeconomic impacts for packaging scenarios at the representative manufacturing location.

Packaging scenario	Average annual output[a]		Average annual income		Average annual employment	
	$ (millions)	Percent impact[b]	$ (millions)	Percent impact	Person-years	Percent impact
Uncanistered	360	1.2	102	0.68	470	0.12
Dual-purpose canister	365	1.2	104	0.69	450	0.12
Disposable canister	310	1.0	89	0.59	470	0.12

a. Annual output and income impacts are expressed as millions of 1998 dollars.
b. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.14.4 for the representative site.

Local Output

The average annual output impacts of each scenario would range from about $310 million to about $365 million (Table 4-48). Output generated from each scenario would increase total local output from between 1.0 percent and 1.2 percent, on average, over the 24-year manufacturing period.

Local Income

The average annual income impacts of each packaging scenario would range from about $89 million to about $104 million (Table 4-48). Income generated from each scenario would increase total local income by between 0.59 percent and 0.69 percent, on average, over the 24-year manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 450 to about 470 work years (Table 4-48). Employment generated from any of the packaging scenarios would increase total local employment about 0.12 percent, on average, over the 24-year manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each disposal container and shipping cask on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (USN 1996a, Sections 3.0, 4.1.1, and Appendix D; TRW 1999c, all), or from conceptual design specifications for technologies still in the planning stages (JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of disposal containers and shipping casks to be manufactured during each packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-49 lists estimated total quantities of materials that DOE would need for each packaging scenario during the 24-year period along with the annual average requirement for each material. For each scenario the largest material requirement by weight would be steel, ranging from about 260,000 to about 280,000 metric tons (280,000 to 310,000 tons).

Table 4-49. Material use (metric tons)[a] for packaging scenarios.

	Basic material use per scenario[b]					
	UC		DISP		DPC	
Material	Total	Annual	Total	Annual	Total	Annual
Aluminum	1,500	63	77	3	1,500	63
Chromium[c]	14,000	590	12,000	500	15,000	620
Copper	36	1	146	6	95	4
Depleted uranium	880	37	1,300	55	120	5
Lead	430	18	1,500	63	3,000	139
Molybdenum[d]	6,000	250	6,600	280	6,000	260
Nickel[e]	29,000	1,200	29,000	1,200	30,000	1,200
Steel	280,000	12,000	260,000	11,000	280,000	12,000

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Chromium estimated as 29 percent of stainless steel and 22 percent of high-nickel alloy.
d. Molybdenum estimated as 13.5 percent of high-nickel alloy.
e. Stainless steel assumed to be 18.5 percent nickel and high-nickel alloy assumed to be 58 percent nickel.

Table 4-50 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium and nickel, consumption for each scenario for the 24-year manufacturing period would be less than 0.5 percent of the annual U.S. production.

Therefore, the use of aluminum, copper, lead, molybdenum, or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 0.48 percent to about 0.59 percent of the annual U.S. production. Most chromium, which is

Table 4-50. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production, for each packaging scenario.

		Packaging scenario[b]					
		UC		DISP		DPC	
Material	Production[c]	Annual	Percent	Annual	Percent	Annual	Percent
Aluminum	5,000,000	63	0.0013	3	0.0001	63	0.0013
Chromium	104,000	590	0.57	500	0.48	620	0.59
Copper	1,900,000	1	0.0001	6	0.0003	4	0.0002
Depleted uranium	14,700[d]	37	0.25	55	0.38	5	0.034
Lead	430,000	18	0.0042	63	0.015	140	0.032
Molybdenum	57,000	250	0.45	280	0.48	260	0.045
Nickel	14,600	1,200	8.3	1,200	8.3	1,200	8.4
Steel	91,500,000	12,000	0.013	11,000	0.012	12,000	0.013

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: Bureau of the Census (1997, Table 1155, page 700, and Table 1244, page 756).
d. Source: USN (1996a, page 4-10).

an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total 24-year program requirement of about 14,000 metric tons (17,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1159, page 702). The total repository program need would be about 1.5 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (Bureau of Census 1997, Table 1155, page 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1158, page 702). The maximum annual program need is a little less than 1 percent of the U.S. consumption and about 0.1 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.38 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (USN 1996a, page 4-10). Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (USN 1996a, page 4-10).

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of disposal containers and shipping casks would be carbon steel, high-nickel alloy, and stainless steel, with either depleted uranium or lead used for

shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of disposal containers and shipping casks and the amounts generated have also been identified.

Based on data in USN (1996a, page 4-13), the analysis estimated annual volumes and quantities of waste produced for each packaging scenario per disposal container and shipping cask manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce disposal containers and casks from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and ion exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-51 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the vessels required for each packaging scenario. The annual average amount of liquid waste generated would range from 3.4 to 3.8 metric tons (approximately 3.7 to 4.2 tons) per year. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-51. Annual average waste generated (metric tons)[a] at the representative manufacturing location for packaging scenarios.

	Packaging scenario[b]		
Waste	UC	DISP	DPC
Liquid	3.4	3.8	3.4
Solid	0.47	0.52	0.47

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

Solid Waste

Table 4-51 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.47 to 0.52 metric ton (approximately 0.52 to 0.57 ton) per year. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted

uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of disposal containers and shipping casks would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in USN (1996a, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety for each scenario. The assessment used demographic data to provide information on the degree to which a scenario would affect minority or low-income populations disproportionately. The evaluation identified as areas of concern those in which disproportionately high and adverse impacts could affect minority or low-income populations.

This evaluation considered the characteristics of the five facilities that manufacture casks or canisters for spent nuclear fuel. For each facility the analysis considered a region defined by an approximately 16-kilometer (10-mile) radius around the site. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (USN 1996a, page 4-18). DOE anticipates very small

impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (USN 1996a, page 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of disposal containers and shipping casks. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced waste for at least 50 years after the start of emplacement. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there were a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Section 2.1.1.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1 square kilometer (250 acres) (TRW 1999a, Attachment I, page I-8).

DOE based selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe

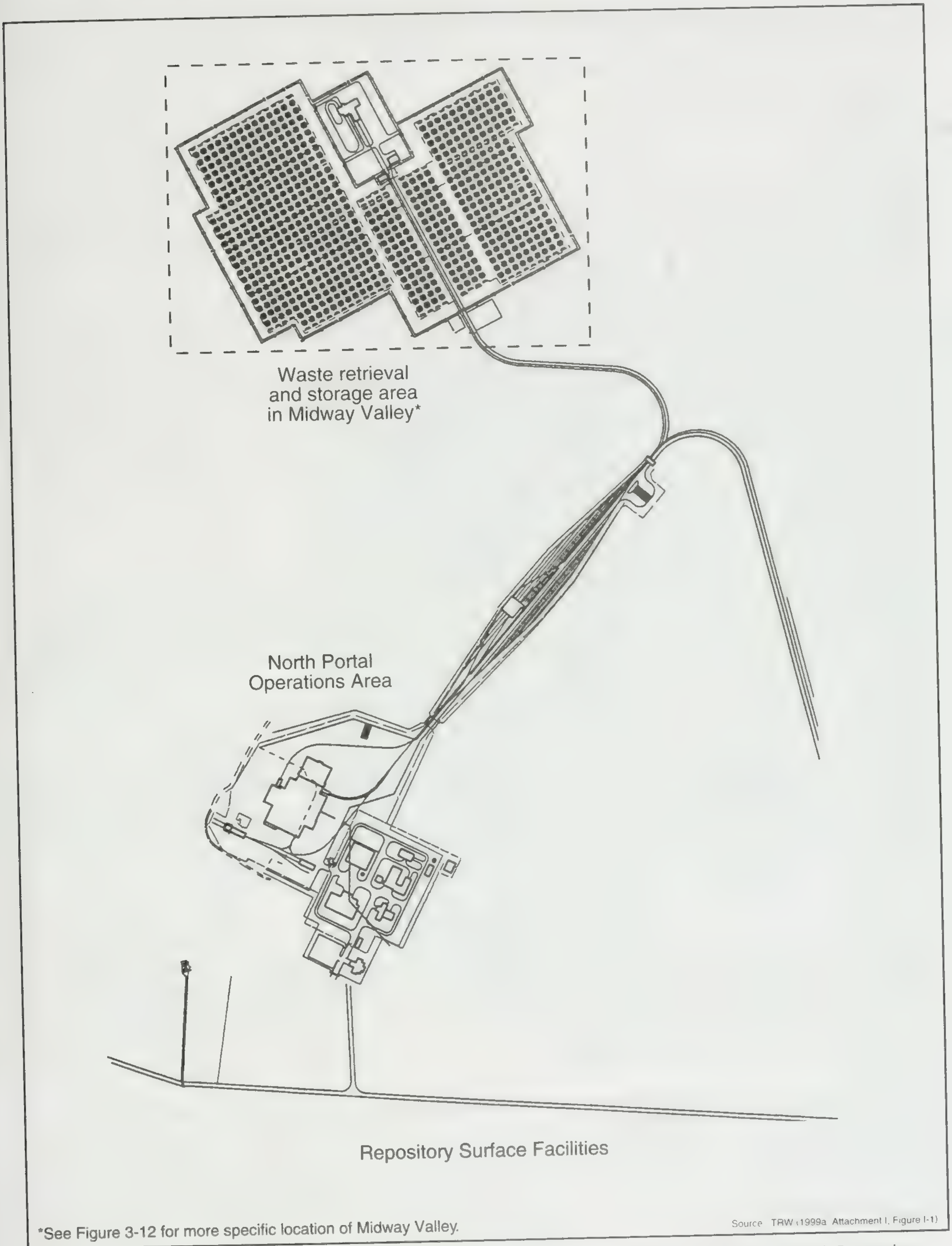


Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

Studies of the strategies and options for retrieval (TRW 1997d, all) indicate it would take about 10 years after a decision to retrieve the emplaced material to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; about 3 years would involve the construction of facilities and storage areas. To accomplish retrieval would require another 11 years, including additional storage area construction. DOE performed an impact analysis for the retrieval contingency only for the high thermal load scenario. The analysis of impacts for this scenario is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

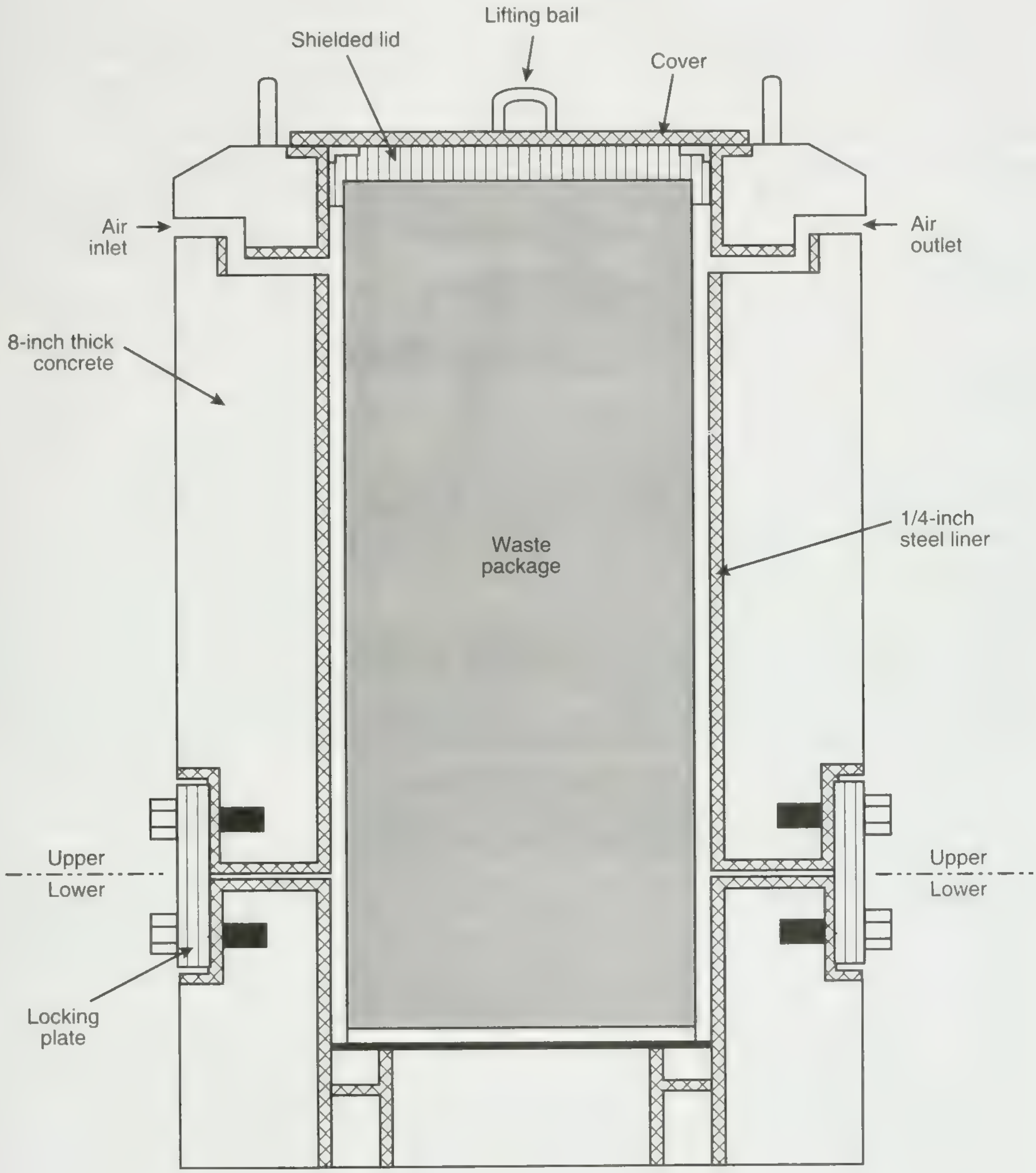
4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land-use impacts during the construction of the Waste Retrieval and Storage Area. DOE would develop a 1-square-kilometer (250-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5) on lands already withdrawn from public use.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.



Source: TRW (1999a, Figure I-4)

Figure 4-6. Typical concrete storage module design, vertical view.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption and PM_{10} in the form of fugitive dust. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-52 lists calculated concentrations for criteria pollutant impacts to the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 1 percent of the applicable regulatory limits in all cases.

Table 4-52. Criteria pollutant impacts to public maximally exposed individual from retrieval (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.23	0.23
Sulfur dioxide	Annual	80	0.022	0.028
	24-hour	365	0.18	0.049
	3-hour	1,300	1.4	0.11
Carbon monoxide	8-hour	10,000	2.1	0.020
	1-hour	40,000	13	0.033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.12	0.23
	24-hour	150 (65)	0.83	0.55

a. Appendix G (Section G.1) contains additional information on air quality.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, about 14 years (3 years of initial construction, followed by 11 years of retrieval operations). Table 4-53 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1 square kilometer (250 acres).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.43 square kilometer (107 acres) of the disturbed land (TRW 1999a, page I-14). Including the areas covered by facilities, roadways, and queuing areas, most of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1 square kilometer (250 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Table 4-53. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during retrieval operations.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	5.5	0.43
80-kilometer[d] population[e] (person-rem)	28	2.1
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.51	0.039
Yucca Mountain noninvolved worker population (person-rem)	0.72	0.23/0.0067[g]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.046	0.0035

a. Appendix G contains detailed information about the air quality analysis.
b. Construction and retrieval activities would last 13 years.
c. About 20 kilometers (12 miles) south of the repository.
d. 80 kilometers = 50 miles.
e. Approximately 28,000 individuals within 80 kilometers of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Operations Area.
g. First value is dose for construction workforce; second value is dose for retrieval workforce.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be outside the probable maximum flood zone (TRW 1999a, page I-8). Therefore, a probable maximum flood in this small wash will avoid the facility.

Potential for Flooding. The location for the Waste Retrieval and Storage Area would be outside the probable maximum flood zone, and the interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. Most of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 110,000 cubic meters (90 acre-feet) a year (TRW 1999a, page I-22; TRW 1999b, page 6-32). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover most of the disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North and South Portal Operations Areas. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 1,600 workers (TRW 1999a, page I-22; TRW 1999b, page 6-32) would be required during retrieval operations and concurrent storage pad construction. Retrieval would be a short-term operation, lasting about 14 years. The repository workforce would decrease to a small maintenance staff after completion of retrieval. Employment during retrieval would be less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate meaningful changes to the region of influence labor force or economic measures. Regional impacts from retrieval operations would probably be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers divided the retrieval period into two subperiods, as follows:

- A construction subperiod during which DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction subperiod, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects this subperiod to last from 2 to 3 years, although construction of the concrete storage pads probably would continue as needed during most of the operations subperiod. No health and safety impacts to the public would be likely during the initial 2- to 3-year construction subperiod.

- An operations subperiod during which DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. This subperiod would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards for the operations subperiod for both surface and subsurface workers. Radiological impacts to the public could occur during the operations subperiod when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4. Section F.4.3 contains detailed information on health and safety impacts which supports the impact summary tables in this section.

Construction Subperiod

As noted above, the only health and safety impacts for this subperiod would be those from industrial hazards during normal workplace activities. Table 4-54 summarizes these impacts. Projected fatality would be about 0.05 and projected lost workday cases would be about 40.

Table 4-54. Industrial hazards health and safety impacts for surface facility workers for retrieval construction subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	69
Lost workdays	33
Fatalities	0.03
Noninvolved workers	
Total recordable cases	14
Lost workdays	7
Fatalities	0.01
All workers (totals)	
Total recordable cases	83
Lost workdays	40
Fatalities	0.04

a. Sources: Impact rates from Table F-46 and full-time equivalent work years from Table F-45.

Operations Subperiod

Industrial Hazard Impacts to Workers. Table 4-55 lists estimated impacts from industrial hazards for both surface and subsurface workers for the operations subperiod. Because the impact estimates would not vary greatly with the thermal load scenario, the table lists only one set of impact values (for the low thermal load). Impacts would be small and about twice those for the construction subperiod.

Table 4-55. Industrial hazards health and safety impacts for retrieval operations subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	35
Lost workday cases	15
Fatalities	0.03
Noninvolved workers	
Total recordable cases	35
Lost workday cases	17
Fatalities	0.04
All workers (totals)	
Total recordable cases	70
Lost workday cases	32
Fatalities	0.07

a. Sources: Tables F-48 and F-49.

Radiological Health Impacts to Workers. Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact. Appendix F contains additional details on the radiological exposure components for the subsurface worker exposure. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.003. The calculated latent cancer fatality incidence to workers for retrieval would be 0.19.

Radiological Health Impacts to the Public. See Table 4-53 for estimated radiological impacts to the public from releases of radon-222 and its decay products through the subsurface ventilation system exhaust.

Table 4-57 lists estimated radiological health impacts to the public over the operations subperiod. The calculated radiological health impacts to members of the public from a retrieval operation would be small. The calculated likelihood of a latent cancer fatality for the maximally exposed individual would be about 2.8×10^{-6}. The calculated latent cancer fatality incidence would be about 0.014.

Table 4-56. Radiological health impacts from retrieval operations.[a,b]

Worker group and impact category	Surface facility workers	Subsurface facility workers	Total/High
Involved workers			
Maximally exposed individual dose[c]	4,400	6,950	6,950[d]
Latent cancer fatality probability	0.002	0.003	0.003[d]
Collective dose (person-rem)	75	380	455
Latent cancer fatality incidence	0.03	0.15	0.18
Noninvolved workers			
Maximally exposed individual dose	280	1,290	1,370[d]
Latent cancer fatality probability	0.0001	0.0005	0.0005[d]
Collective dose (person-rem)	6	22	28
Latent cancer fatality incidence	0.002	0.009	0.01
All workers (totals)[e]			
Collective dose (person-rem)	81	400	480
Latent cancer fatality incidence	0.03	0.16	0.19

a. Sources: Appendix F, Tables F-51 and F-52.
b. There would be no radiological health impacts to the public during the construction subperiod.
c. For 11-year period of operation (millirem).
d. Values are not totals, but the largest of the compounds.
e. Totals might differ from sums of values due to rounding.

Table 4-57. Radiological health impacts to the public for retrieval operations period.[a,b]

Worker group and impact category	Impact
Individual	
Maximally exposed individual (millirem)	5.5
Latent cancer fatality probability	2.8×10^{-6}
Population	
Collective dose (person-rem)	28
Latent cancer fatality incidence	0.014

a. Source: Table 4-49.
b. There would be no radiological health impacts to the public during the construction subperiod.

Radiological Health Impacts to the Public. The potential for exposure of members of the public to radiological materials released as a result of retrieval operations would exist only during the operations subperiod. These impacts are summarized in Table 4-57. The predicted incidence of latent cancer fatality would be about 0.1.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened.

Summary of Impacts

Industrial Health and Safety Impacts to Workers for Retrieval. Table 4-58 summarizes the industrial health and safety impacts to workers from the retrieval construction and operations subperiods. Estimated fatalities would be low, about 0.1, with about 72 lost workday cases.

Radiological Impacts to Workers. Radiological impacts to workers from retrieval would occur primarily during the operations subperiod, as summarized in Table 4-56.

Table 4-58. Overall industrial hazards health and safety impacts for retrieval.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	100
Lost workday cases	48
Fatalities	0.07
Noninvolved workers	
Total recordable cases	48
Lost workday cases	24
Fatalities	0.04
All workers (totals)	
Total recordable cases	150
Lost workday cases	72
Fatalities	0.11

a. Sources: Tables 4-58 and 4-59

The handling accident scenario applicable for these operations would be bounded by the transporter

runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DOE 1997m, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with meaningful consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft penetration potential would not be sufficient to breach the thickness of the waste package (Davis 1998, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.10 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Worker traffic noise levels would also be less because fewer workers would commute to the site. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 540,000 cubic meters (410,000 cubic yards) of concrete and 42,000 metric tons (46,000 tons) of steel, which would not affect the regional supply capacity. About 10,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 110,000 cubic meters (140,000 cubic yards) of concrete would be required to build 10,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 10,000 concrete storage modules to the site would be comparable to those for shipping about 10,000 storage containers to the site (see Section 6.2.5).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-59 summarizes impacts to utilities, energy, and materials.

Table 4-59. Utilities, energy, and materials for retrieval.[a,b,c]

	Electric		Fossil fuel	Construction materials	
Location	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.2	82	20	540	42
Subsurface	7.7	270 - 520	2.5	0	0
Totals	**8.9**	**350 - 600**	**22.5**	**540**	**42**

a. Sources: TRW (1999a, pages I-22 to I-24); TRW (1999b, page 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 11 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated 12,000 cubic meters (420,000 cubic feet) of construction debris, 2,400 cubic meters (85,000 cubic feet) of sanitary and industrial solid waste, and 450 cubic meters (16,000 cubic feet) of hazardous waste (TRW 1999a, page I-22). Based on operations generation rates (TRW 1999a, page 76; TRW 1999b, page 6-34), the retrieval of the storage containers would generate an estimated 5,100 cubic meters (180,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. The National Capacity Assessment

Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income populations in the Yucca Mountain region or to the workers during retrieval operations. In addition, because disproportionate impacts to minority or low-income populations from repository construction and operation would be unlikely, none would be likely from retrieval.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and that emplacement would occur over a 24-year period ending in 2033 (70,000 MTHM at approximately 3,000 MTHM per year). The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 10,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. However, because the amounts of these materials would be smaller than those analyzed for the retrieval contingency, the overall impacts from the Waste Staging Facility would be smaller than those described in Section 4.2.1.

5

Environmental Consequences of Long-Term Repository Performance

5. ENVIRONMENTAL CONSEQUENCES OF LONG-TERM REPOSITORY PERFORMANCE

This chapter describes potential human health impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure of a repository at Yucca Mountain. The impact calculations assumed that the current population in the Yucca Mountain region would remain constant, as discussed in Section 5.2.4.1. The chapter also describes the peak radiation dose during the first 1 million years after closure. Closure of a repository would include the following events, which are analyzed in Chapter 4:

- Sealing of the underground emplacement drifts
- Backfilling and sealing of other underground openings
- Removal of the surface facilities
- Construction of surface monuments to discourage human intrusion
- Creation of institutional controls, including land records and monuments, to identify the location of the repository

In addition, this chapter discusses estimates of potential biological impacts from radiological and chemical groundwater contamination; potential environmental impacts of such contamination and potential biological impacts from the long-term production of heat by decay of the radioactive materials that would be disposed of in a repository at Yucca Mountain; and potential environmental justice impacts. These would be the only other potential impacts likely from the long-term postclosure system. There would be no repository activities; no changes in land use, employment of workers, water use or water quality other than from the transport of radionuclides; and no use of energy or other resources, or generation or handling of waste after closure of a repository. Therefore, analysis of impacts to land use, noise, socioeconomics, cultural resources, surface-water resources, aesthetics, utilities, or services after closure is not required. As part of closure activities, the U.S. Department of Energy (DOE) would return the land to its original contour and erect appropriate monuments marking the repository, which would result in some minor impacts on aesthetics depending on the exact design of the monuments (currently undetermined). Impacts from closure are discussed in Chapter 4. After the completion of closure, risk of sabotage or intruder access would be highly unlikely. Chapter 4 (Section 4.1.8.3) discusses the potential for sabotage prior to closure. Section 5.7.1 discusses potential impacts from an intruder after closure.

DOE performed this analysis of potential impacts after repository closure for three thermal load scenarios. The selected thermal load would be attained by varying the spacing between emplacement drifts and between waste packages in the drifts. The high thermal load of 85 metric tons of heavy metal (MTHM) per acre would emplace radioactive materials over the smallest repository area. The intermediate thermal load of 60 MTHM per acre would emplace radioactive materials over a larger repository area. The low thermal load of 25 MTHM per acre would emplace the radioactive materials over the largest repository area.

This assessment considered the following three transport pathways (means by which contamination could reach the biosphere) from spent nuclear fuel and high-level radioactive waste to reach human populations and cause health consequences:

- Groundwater
- Surface water
- Atmosphere

The principal pathway would result from rainwater migrating down through the unsaturated zone into the repository, dissolving some of the material in the repository, and carrying contaminants from the dissolved material downward through the unsaturated zone and through the groundwater system to locations where human exposure could occur. A surface-water pathway would arise only from groundwater that reached the surface at a discharge location, so the assessment considered surface-water consequences along with groundwater consequences. An airborne pathway could result from radioactive carbon-14 from spent nuclear fuel that migrated to the surface in the form of carbon dioxide gas that mixed with the atmosphere. Spent nuclear fuel contains other gases such as various xenon isotopes and krypton-85, but their very short half-lives would preclude their presence by the time of closure. Radon generated by uranium decay would not be a problem in the Yucca Mountain vicinity because closed residential structures would be unlikely on Yucca Mountain (see Section 5.2.4.1).

The assessment estimated potential human health impacts from the groundwater transport pathway at four locations in the Yucca Mountain groundwater hydrology region of influence: water wells 5, 20, and 30 kilometers (3, 12, and 19 miles) from the repository and the nearest surface-water discharge point [about 80 kilometers (50 miles) from the repository]. These consequences are in terms of radiological dose and the probability of a resulting latent cancer fatality. A latent cancer fatality is a death from cancer resulting from, and occurring sometime after, exposure to ionizing radiation or other carcinogens.

DOE assessed the processes by which waste could be released from a repository at Yucca Mountain and transported to the environment. The analysis used computer programs developed to assess the release and movement of radionuclides and hazardous materials in the environment. Some of the programs analyzed the behavior of engineered components such as the waste package, while others analyzed natural processes such as the movement of groundwater. The programs are based on the best available geologic, topographic, and hydrologic data and current knowledge of the behavior of the materials proposed for the system. The assessment used data from the Yucca Mountain site characterization activities, material tests, and expert opinions as input parameters to estimate human health consequences. Many parameters used in the analysis cannot be exactly measured or known; only a range of values can be known. The analysis accounted for this type of uncertainty; thus, the results are ranges of health consequences.

The long-term performance assessment considered human health impacts during the first 10,000 years after repository closure and the peak dose during the first 1 million years after repository closure. Estimates of potential human health impacts from the undisturbed evolution of a repository included the effects of such natural processes as corrosion of waste packages, dissolution of waste forms, and changing climate. In addition, the assessment examined the effects of such disturbances as exploratory drilling, seismicity, or volcanic events.

DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste.

5.1 Inventory for Performance Assessment Calculations

DOE proposes to dispose of between 10,000 and 11,000 waste packages containing as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain. There are several different types of disposal containers for commercial spent nuclear fuel and different container designs for DOE spent nuclear fuel and high-level radioactive waste. The exact number of waste packages, therefore, would depend on various options in the proposed design. This long-term consequence assessment identified the inventory by the source categories of waste material to be disposed of (commercial spent nuclear fuel, DOE spent nuclear fuel, weapons-usable plutonium, and high-level

radioactive waste). For purposes of modeling, the inventory for each of the categories was averaged into an appropriate number of packages, each with identical contents. The average of the modeled inventories resulted in a total of nearly 12,000 idealized packages (slightly higher than the actual number of waste packages that would be emplaced) in three basic types, as described in the sections below. Figure 5-1 shows the averaging process.

INVENTORY OF RADIOACTIVE MATERIALS

There are more than 200 radionuclides in the waste inventory (see Appendix A). To perform impact calculations efficiently, this evaluation used a reduced number of radionuclides (see Appendix I). Those radionuclides eliminated from further consideration had at least one of the following characteristics:

- Radionuclides with short half-lives (generally less than several hundred years) that are not decay products of long-lived radionuclides (for example, krypton-85, xenon isotopes, and cesium-137)
- Radionuclides with high chemical sorption or low solubility that will decay before arriving at a human exposure point (for example, americium-241 and nickel-59)
- Radionuclides with low biosphere dose conversion factors that convert concentration to dose [relatively high radionuclide concentrations in groundwater would be required to produce a given dose compared to other radionuclides (for example, zirconium-93)]

TERMS RELATED TO RADIOACTIVE MATERIALS

A **curie** is a unit of radioactivity equal to the amount of a radioactive isotope that decays at a rate of 37 trillion disintegrations per second.

A **half-life** is the period during which radioactive decay causes half a given amount of a radionuclide to change to some other radionuclide or stable element.

During **decay**, the atom loses particles such as neutrons, electrons, or protons, and transforms to a different atomic mass or, in some cases, to a different atomic number and, ultimately, to a different element possessing different properties.

The large amounts of uranium in the repository would produce large quantities of radon as a decay product. The longest-lived radon isotope is radon-222, with a half-life of 4 days (CRC 1997, page 4-24); however, the large amount of uranium would result in a steady level of radon over time. The only potential transport and exposure pathway for radon would be the atmosphere because radon would not travel far enough in water to reach a receptor before decaying. The analysis did not consider radon for a gas pathway because it is a health problem only when trapped in closed structures (that is, it decays rapidly to nongaseous elements), and there should be no closed structures at the top of the mountain (see Section 5.2.4.1). Based on these considerations and previous performance analysis results at Yucca Mountain (TRW 1995b, all), DOE selected nine dominant radionuclides for analysis. Appendix I and previous performance analysis results at Yucca Mountain (Barnard et al. 1992, all; TRW 1995b, all) and the Viability Assessment (DOE 1998a, Volume 3, pages 3-95 to 3-99) contain more details on the inventory selection for the long-term performance models.

Table 5-1 lists the averaged radionuclide inventory in a waste package at the time of emplacement for the nine selected radionuclides for the following three sources:

- Commercial spent nuclear fuel
- DOE spent nuclear fuel
- High-level radioactive waste (including weapons-usable plutonium)

a. PWR = pressurized-water reactor.
b. BWR = boiling-water reactor.
c. MTHM = metric tons of heavy metal.

Note: For purposes of illustration, waste packages are shown without lids.

Source: Modified from DOE (1998a, Volume 3, page 3-98)

Figure 5-1. Inventory averaging (abstraction) process.

Table 5-1. Average radionuclide inventory (curies unless otherwise noted) per waste package for performance assessment calculations.[a]

Isotope	Half-life (years)	Commercial SNF[b] (7,760 idealized packages)	DOE SNF (2,546 idealized packages)	HLW[c] (1,663 idealized packages)
Carbon-14	5.7×10^{3}	12	0.31	0
Iodine-129	1.6×10^{7}	0.29	0.0057	0.000042
Neptunium-237	2.1×10^{6}	11	0.15	0.74
Protactinium-231	3.3×10^{4}	5.1[d]	0.66[d]	0.036[d]
Plutonium-239	2.4×10^{4}	3,100	160	24
Plutonium-242	3.9×10^{5}	17	0.11	0.02
Selenium-79	6.5×10^{4}	3.7	0.089	0.29
Technetium-99	2.1×10^{5}	120	2.6	30
Uranium-234	2.5×10^{5}	21	0.54	0.9

a. Source: DOE (1998a, Volume 3, Table 3-14, page 3-96).
b. SNF = spent nuclear fuel.
c. HLW = high-level radioactive waste.
d. Grams per waste package.

Some of the values in Table 5-1 are adjusted for ingrowth of radionuclides as products of decay of other radionuclides and are not an exact match with the inventory data in Appendix A. For example, americium-241, with a half-life of about 432 years, decays to neptunium-237. Because the waste packages are designed to last much longer than this (thousands of years), most of the americium-241 would decay to neptunium-237 before a waste package could fail. The analysis increased the inventory of neptunium-237 in the commercial spent nuclear fuel waste packages by 58 percent to account for this radioactive decay. A total of 11,969 idealized packages was used in the analysis.

DOE used a screening analysis to identify those chemically toxic materials that would require more detailed analysis (see Appendix I). The analysis started with a proposed inventory of all materials in the repository at the time of closure. This inventory included construction materials, waste package materials, and the contents of the waste packages. For each material, the screening process considered total inventory, solubility of the material in water, and chemical toxicity. The analysis found that earthen and concrete materials had no potential toxicity. The only known organic materials would be additives to the concrete (binders and conditioners) that either are inherently nontoxic or could break down completely in response to exposure to high radiation fields (TRW 1999b, pages 4-56 to 4-65) for 100 years or more before closure.

The first step in the screening process was to eliminate all nontoxic materials. In the second step, more materials were eliminated because their total quantity would be very low and dilution in the repository environment would reduce their concentration to below toxic levels before they entered the saturated groundwater system. Other materials would have low concentrations because of their very low solubilities. Low quantities or low concentrations accounted for the elimination of most hazardous materials in the spent nuclear fuel and high-level radioactive waste. The final step in the screening process was to eliminate materials that would not be transported to a surface drainage point or well in sufficient concentrations to pose a human health hazard.

Based on the screening analysis, DOE selected chromium, molybdenum, and uranium for detailed assessments of their potential human health impacts. Sections 5.6.1 through 5.6.3 describe these impacts. Chromium and molybdenum were retained for further analysis because they would be present in large quantities and remain in very soluble toxic forms. Uranium was retained because it would be present in very large quantities, is quite soluble, and is toxic as a heavy metal. The nickel-chromium alloy (Alloy-22) portion of the disposal container nominally would be 21.25 percent chromium (ASTM 1994, all). In addition, there would be approximately 4.3 kilograms (9.5 pounds) of chromium in a

pressurized-water reactor fuel assembly and 1.9 kilograms (4.2 pounds) in a boiling-water reactor fuel assembly (see Appendix A). About 70 percent of the chromium in the repository would be in Alloy-22 disposal containers; the remainder would be in the fuel assemblies. All of the molybdenum would be in the Alloy-22, which nominally is about 13.5 percent molybdenum. DOE estimated the uranium inventory by using the repository capacity (in MTHM) to consider chemical toxicity. This is a very conservative approach because some of the heavy metal in spent nuclear fuel is plutonium and thorium, and the high-level radioactive waste has very small quantities of uranium because it is the byproduct of uranium and plutonium separations. The MTHM basis of high-level radioactive waste is the heavy metal content of the fuel from which the material was derived during the separation process. Plutonium was not included in the assessment of chemical toxicity because (in contrast to uranium) its radiotoxicity exceeds its chemical toxicity. Table 5-2 lists the total potential inventory of chromium, molybdenum, and uranium in the repository.

Table 5-2. Total inventory of chemically toxic materials in the repository.[a]

Element	Metric tons[b]
Chromium	14,000
Molybdenum	6,200
Uranium	70,000

a. Source: Appendix I, Table I-10.
b. To convert metric tons to tons, multiply by 1.1023; numbers are rounded to two significant figures.

5.2 System Overview

Radioactive materials in the repository would be placed about 300 meters (980 feet) beneath the surface (DOE 1998a, Volume 3, page 3-3). In physical form, the emplaced materials would be almost entirely in the form of solids with a very small fraction of the total radioactive inventory in the form of trapped gases (see Section 5.5). With the exception of a small amount of radioactive gas in the fuel rods, the primary means for the radioactive and chemically toxic materials to contact the biosphere would be along groundwater pathways. The materials could pose a threat to humans if the following sequence of events occurred:

- The waste packages and their contents were exposed to water
- Radionuclides or chemically toxic materials in the package materials or wastes became dissolved or mobilized in the water
- The radionuclides or chemically toxic materials were transported in water to an aquifer, and the water carrying radionuclides or chemically toxic materials was withdrawn from the aquifer through a well or at a surface-water discharge point and used directly by humans for drinking or in the human food chain (such as through irrigation or watering livestock)

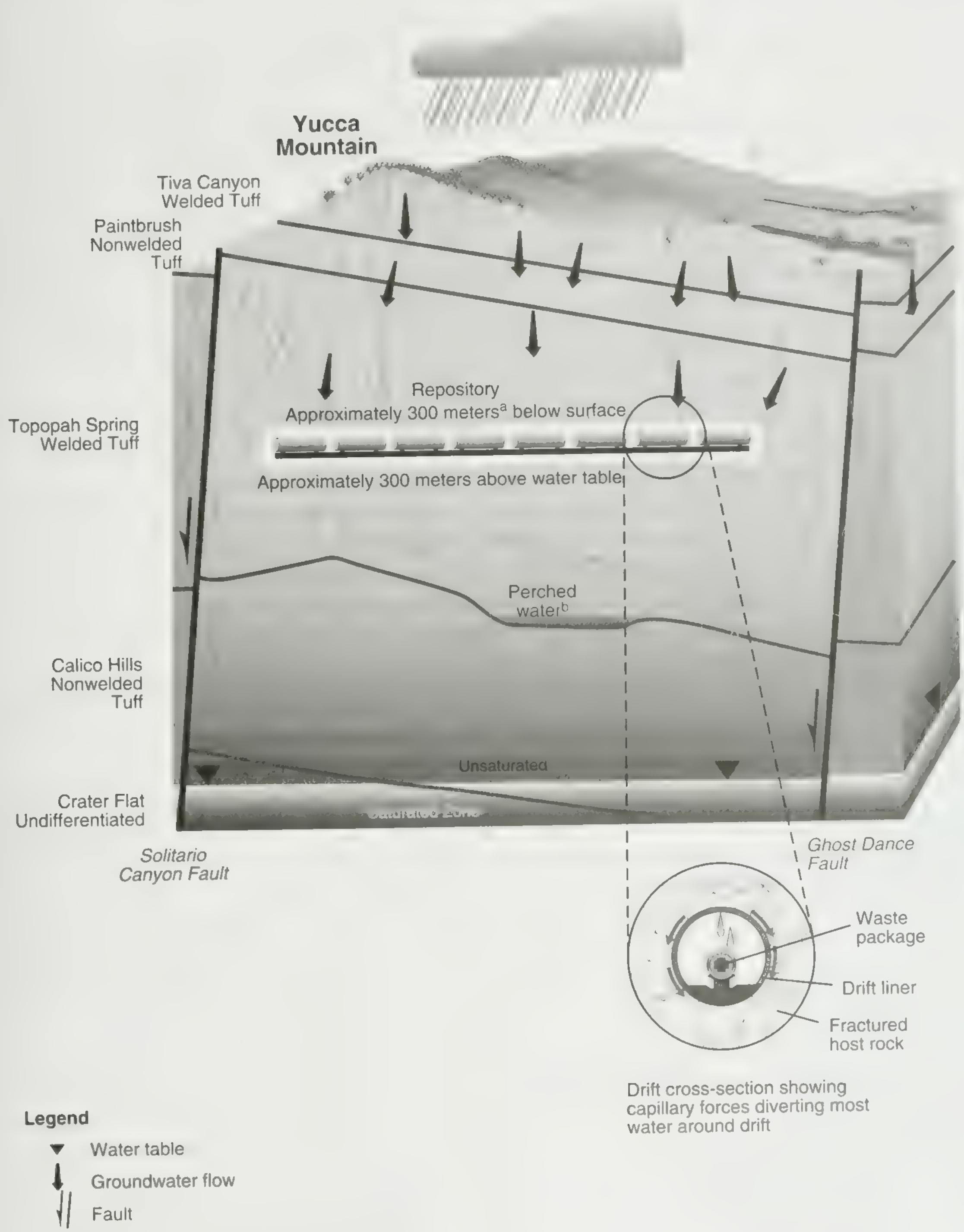
WASTE PACKAGE

A *waste package* consists of the waste form and any containers (disposal container, barriers, and other canisters), spacing structure or baskets, shielding integral to the container, packing in the container, and other absorbent materials immediately surrounding an individual disposal container, placed inside the container, or attached to its outer surface. The waste package begins its existence when the outer lid welds are complete and accepted and the welded unit is ready for emplacement in the repository.

Thus, the access to and flow of contaminated water are the most important considerations in determining potential health hazards.

5.2.1 COMPONENTS OF THE NATURAL SYSTEM

Figure 5-2 is a simplified schematic of a repository at Yucca Mountain. It shows the principal features of the natural system that could affect the long-term performance of the repository. Yucca Mountain is in a



a. To convert a meters to feet, multiply by 3.2808.
b. Perched water is a localized pocket of groundwater.

Figure 5-2. Components of the natural system.

semiarid desert environment where the average annual precipitation is between 100 and 250 millimeters (4 and 10 inches), varying by specific location over the immediate region (DOE 1998a, Volume 1, page 2-29). The water table is an average of 600 meters (2,000 feet) below the surface of the mountain. The proposed repository would be in unsaturated rock approximately midway between the desert environment and the water table.

> **HYDROGEOLOGIC TERMS**
>
> **Saturated zone:** The area below the water table where all spaces (fractures and rock pores) are completely filled with water.
>
> **Unsaturated zone:** The area between the surface and the water table where only some of the spaces (fractures and rock pores) are filled with water.
>
> **Matrix:** The solid, but porous, portion of the rock.

The water table is the boundary between the unsaturated zone above and the saturated zone below. In the subsurface region above the water table, the rock contains water but the water does not fill all the open spaces in the rock. Because the open spaces are only partially filled, this region is called *the unsaturated zone*. Water in the unsaturated zone tends to move generally downward in response to capillary action and gravity. In contrast, water fills all the open spaces in the rock below the water table, so this region is called the *saturated zone*. Water in the saturated zone tends to flow laterally from higher to lower pressures. Both zones contain several different rock types, as shown in Figure 5-2. The layers of major rock types in the unsaturated zone at the Yucca Mountain site are the Tiva Canyon welded, Paintbrush nonwelded, Topopah Spring welded, Calico Hills nonwelded, and Crater Flat undifferentiated tuffs. Figure 5-2 shows two of the faults at the proposed site—the Ghost Dance fault that occurs within the repository block and the Solitario Canyon Fault that forms the western boundary of the repository block. Faults are slip zones where rock units have become displaced either vertically, laterally, or diagonally, resulting in the rock layers being discontinuous. These slip zones tend to form a thin plane in which there is more open space that acts as a channel for water. Some faults tend to fill with broken rock formed as they slip, so they take on a very different flow property from that of the surrounding rock. The proposed repository would be in the Topopah Spring welded tuff in the unsaturated zone, about 300 meters (980 feet) below the surface and approximately 300 meters above the water table (DOE 1998a, Volume 3, page 3-3).

When it rains in the Yucca Mountain vicinity, most of the water runs off and a very limited amount infiltrates the rock on the surface of the mountain. Some of the water that remains on the surface or infiltrates the rock evaporates back into the atmosphere (directly or through plant uptake and evapotranspiration). The very small amount of water that infiltrates the rock and does not evaporate percolates down through the mountain to the saturated zone. Water that flowed through the unsaturated zone into the proposed repository could dissolve some of the waste material, if there was a breach in the package containment, and could carry it through the groundwater system to the accessible environment, where exposure to humans could occur.

5.2.2 COMPONENTS OF THE WASTE PACKAGE

Under the Proposed Action, spent nuclear fuel and high-level radioactive waste would be placed in cylindrical metal *disposal containers*. After being sealed, a disposal container would be called a *waste package*. Each waste package would have a 10-centimeter (4-inch)-thick carbon-steel outer shell, and an inner shell of a 2-centimeter (0.8-inch)-thick nickel-chromium alloy (called *Alloy-22*). The Alloy-22 would corrode 100 to 1,000 times slower than the carbon steel. Commercial spent nuclear fuel, which would comprise 98 percent of the radioactivity in the repository, would be additionally protected by a thin cladding of a zirconium alloy. Approximately 1 percent (by volume) of the commercial spent nuclear

fuel would have cladding made of stainless steel rather than zirconium alloy. Commercial spent nuclear fuel would account for 75 percent of the total number of waste packages. Zirconium alloy has a corrosion rate much lower than that of Alloy-22. Water would not reach the fuel until there were openings in the carbon steel, the Alloy-22, and the cladding material. About 3.3 percent of the proposed repository inventory would be DOE spent nuclear fuel that would have a variety of cladding. Cladding was not considered to be a transport barrier for DOE spent nuclear fuel. The high-level radioactive waste form would not have cladding; this material would be in stainless-steel canisters, which for conservatism were not given any value as barriers.

5.2.3 VISUALIZATION OF THE REPOSITORY SYSTEM FOR ANALYSIS OF LONG-TERM PERFORMANCE

In general, the repository system was modeled as a series of processes linked together, one after the other, spatially from top to bottom in the mountain. From a computer modeling standpoint, it is important to break the system into smaller portions that relate to the way information is collected. In reality, an operating repository system would be completely interconnected, and virtually no process would be independent of other processes. However, the complexity of such a system demands some idealization of the system for an analysis to be performed.

In the following presentation, the processes are discussed in relation to the key attributes of the repository safety strategy. The four key attributes are:

- Limited water contacting waste package
- Long waste package lifetime
- Slow release of radionuclides from the waste
- Reduction in the concentration of radionuclides and chemically toxic material during transport from the waste to a point of human exposure

Along with the processes, this chapter discusses the models used to analyze them. The analysis included models associated with abnormal or disruptive events like volcanism, seismicity, and human intrusion. These events, if they occurred, would affect the undisturbed repository. The *Viability Assessment of a Repository at Yucca Mountain* contains details of the model construction and the input and output parameters (DOE 1998a, Volume 3, pages 3-1 to 3-162), and Appendix I, Section I-4 discusses the changes made for this EIS. The following sections summarize the expected behavior of the major components.

5.2.3.1 Limited Water Contacting Waste Package

Changes in climate over time provide a range of conditions that determine how much water could fall onto and infiltrate the ground surface. Based on current scientific understanding, the current climate is estimated to be the driest that the Yucca Mountain vicinity will ever experience. All future climates were assumed to be similar to or wetter than current conditions. The *climate* model provides a forecast of future climates based on information about past patterns of climates (DOE 1998a, Volume 3, pages 3-8 and 3-9). The model represents future climate shifts as a series of instant changes between the current dry climate, a long-term average climate with about twice the precipitation of the dry climate, and a very wet climate with about three times the precipitation of the dry climate. The water from precipitation that is not lost back to the atmosphere by evaporation or transpiration enters the unsaturated zone flow system. Water infiltration is affected by a number of factors related to climate, such as an increase or decrease in

vegetation on the ground surface, total precipitation, air temperature, and runoff. The *infiltration* model uses data collected from studies of surface infiltration in the Yucca Mountain region (DOE 1998a, Volume 1, page 2-41). It treats infiltration as variable in the region, with more occurring along the crest of Yucca Mountain than along its base. The results of the climate model affect assumed infiltration rates.

Water generally moves downward in the rock matrix and in rock fractures. The rock mass at Yucca Mountain is composed of volcanic rock that is fractured to varying degrees as a result of contraction during cooling of the original, nearly molten rock and as a result of extensive faulting in the area. Water flowing in the fractures moves much more rapidly than the water moving through the matrix. In some locations, some of the water collects into locally saturated zones in the rock or is diverted laterally by differences in the rock properties. The overall unsaturated flow system is very heterogeneous, and the locations of flow paths, velocities, and volumes of groundwater flowing along these paths are likely to change many times over the life of the repository system. The *unsaturated zone flow* model assumes constant flow over a specific time period (taken from the infiltration model) and generates three-dimensional flow fields for three different infiltration boundary conditions, the three different climates described above, and several values of rock properties (DOE 1998a, Volume 3, pages 3-2 to 3-23). Because this model can assess the movement of materials leached from failed waste packages, the analysis used it to analyze the period after which most of the heat effects would have subsided and assumed there would be no further influence of heat on unsaturated zone flow fields.

The heat generated by the decay of nuclear materials in the repository would cause the temperature of the surrounding rock to rise from the time of emplacement until approximately 15 to 25 years after repository closure (DOE 1998a, Volume 3, page 3-37). The water and gas in the heated rock would be driven away from the proposed repository during this period, referred to in this document as the *thermal pulse*. This would occur under all thermal load scenarios discussed in this EIS. The thermal output of the materials would decrease with time; eventually, the rock would return to its original temperature, and the water and gas would flow back toward the proposed repository. The *mountain-scale thermal hydrology* model uses two-dimensional cross-sections taken from the three-dimensional, site-scale unsaturated zone flow model (see Appendix I, Section I.4). It provides the air mass-fraction and gas-flux near the repository drift to the near-field geochemical process models.

Some conceptual uncertainty exists regarding the influence of heat on water movement in the unsaturated zone. Some analysts (DOE 1998o, all) have suggested there could be a large thermal influence on the movement and chemistry of water after the repository cooled. Specifically, differences in temperature could focus water flow back toward the repository, resulting in much higher seepage rates than this analysis considered in the period after the thermal pulse. Therefore, this view would yield different results than the current drift-seepage models. Such a focus could have a large effect on the movement of radionuclides in the unsaturated zone. DOE is planning to conduct studies to measure the influence of temperature differences on water movement (DOE 1998a, Volume 4, page 3-17).

In addition, there is uncertainty concerning the influence of high temperatures on rock properties. The high temperatures might cause mineral alterations and produce long-term alteration in unsaturated zone water chemistry. However, some sensitivity studies on alternative chemistry scenarios suggest this would not have a large effect on the results (DOE 1998a, Volume 3, pages 4-85 to 4-86). Specifically, the effect of loss of sorptive capacity in the unsaturated zone was examined and would not have a large effect on biosphere dose. DOE is planning to conduct studies of the influence of heat on the chemical environment (DOE 1998a, Volume 4, page 3-22).

After the water returned to the repository walls, it would drip into the repository but only in a relatively few places. The number of seeps that could occur and the amount of water that would be available to drip would be restricted by the low rate at which water flows through Yucca Mountain, which is in a semiarid

area. Drips could occur only if the hydrologic properties of the rock mass caused the water to concentrate enough to feed a seep. Over time, the number and locations of seeps would increase or decrease, corresponding to increased or decreased infiltration based on changing climate conditions. The *seepage flow* model calculates the amount of seepage that could occur based on input from the unsaturated zone flow model (DOE 1998a, Volume 3, pages 3-11 and 3-12). The basic conceptual model for seepage suggests that openings in unsaturated rock act as capillary barriers and divert water around them. For seepage to occur in the conceptual model, the rock pores at the drift wall would have to be locally saturated. Drift walls could become locally saturated by either disturbance to the flow field caused by the drift opening or variability in the permeability field that creates channeled flow and local ponding. Of the two reasons, the variability effect is more important. Drift-scale flow calculations made with uniform hydrologic properties suggest that seepage would not occur at expected percolation fluxes. However, calculations that include permeability variations do estimate seepage, with the amount depending on the hydrologic properties and the incoming percolation flux. Ongoing studies suggest that water travels through the unsaturated zone at highly variable rates from less than 100 years to thousands of years (see Chapter 3, Section 3.1.4.2.2).

5.2.3.2 Long Waste Package Lifetime

Because a repository at Yucca Mountain would be located above the water table in the unsaturated zone, the most important process controlling waste package lifetime is whether water would drip from the seeps on the package.

The location of the seeps would depend to some extent on the natural conditions of the rock but also on the alterations caused by construction of a repository. Alterations such as increased fracturing might be caused by mechanical processes related to drilling the drifts or by thermal heating and expansion of the drift wall. The alterations in the seepage could also be caused by chemical alterations occurring as the engineered materials dissolved in water and reprecipitated in the surrounding rock, closing the pores and fractures. The chemistry in the drift would change continually because of the complex interactions among the incoming water, circulating gas, and materials in the drift (for example, concrete from the liner or metals in the waste package). The changes in chemistry would be strongly influenced by heat during the thermal pulse.

The *drift-scale thermal hydrology* model calculates waste package surface temperature and relative humidity in the drift for different waste package types in several regions of the repository and provides these values to the waste package degradation model (DOE 1998a, Volume 3, pages 3-29 to 3-33). This model also calculates average waste form temperature and liquid saturation in the invert in the regions of the repository and provides these values to the waste form degradation and unsaturated zone transport models. Finally, it calculates average drift wall temperature, relative humidity, and liquid saturation for the invert, and provides these values to the near-field geochemistry models.

In the reference design, the radioactive waste placed in the proposed repository would be enclosed in a two-layer waste package. The layers would be of two different materials that would fail at different rates and from different mechanisms as they were exposed to various repository conditions. As described in Section 5.2.2, the outer layer would be carbon steel and the inner layer a high-nickel alloy metal. Where water dripped on the waste packages, the packages would corrode over time. The breaches probably would occur as deep, narrow pits or as broader areas called *patches*. The changing thermal, hydrologic, and chemical conditions in the repository would influence the corrosion rate of the waste packages.

The *near-field geochemistry* model calculates the interaction of water flowing through the drift with the material in the drift (DOE 1998a, Volume 3, pages 3-39 to 3-73). Equilibrium calculations generate a set of chemical composition parameters that the *waste-package degradation* model uses. In addition, the

waste-package degradation model uses information from the drift-scale thermal hydrology model and the near-field geochemistry model to determine a corrosion rate that would vary at different areas on a given waste package (patch to patch and pit to pit) and from waste package to waste package. The surface of a conceptual waste package would have 400 separate areas called patches (DOE 1998a, Volume 3, pages 3-73 to 3-90). This model calculates the cumulative number of package failures as a function of time (a *failure* would be the first pit penetration or first patch penetration), the average size of failed patches over time, and the average pit area per package over time. The final calculations include assumed failures (to be conservative) that could be caused by manufacturing defects or mishandling.

The analysis assessed the possible effect of chemically toxic materials. The analysis did not identify any organic materials as being present in enough quantities to be toxic. A screening process eliminated most other materials because they were not of concern for human health effects (see Appendix I, Section I.3.2). Some of the components of the high-nickel alloy (such as chromium and molybdenum) were of sufficient quantity and possible toxicity to warrant an assessment of their transport into the biosphere. The rate of release of these materials was taken directly from the waste-package degradation modeling. These contaminants were modeled in the same way as the radionuclides in the models discussed below.

5.2.3.3 Slow Release of Radionuclides from Waste Package

If seepage water eventually entered a waste package through holes caused by corrosion, it could contact the radioactive material inside. Most of the material would be from commercial reactors, but some would be defense high-level radioactive waste, immobilized waste form incorporating formerly weapons-usable plutonium, and DOE spent nuclear fuel. Because most of the material would be commercial spent nuclear fuel, the long-term performance of the repository system would depend primarily on that material. The next two paragraphs discuss important considerations about commercial spent nuclear fuel.

The water would first contact the very thin layer [about 570 micrometers (0.022 inch) thick] of a zirconium alloy that would cover the surface of most of the fuel elements. This layer, called cladding, would have to be breached by mechanical or chemical processes before the radioactive fuel pellets could be exposed. *Cladding degradation* by chemical or physical processes such as corrosion or creep rupture is specified directly as a fraction of failed cladding over time (DOE 1998a, Volume 3, pages 3-100 to 3-103). This model includes other cladding degradation modes such as mechanical failure. It provides the cladding failure rate to the waste-form degradation and engineered-barrier system transport models.

After the cladding failed, individual fuel elements would start to degrade, making the radionuclides available for transport. The degradation process could involve several stages because the waste forms would sometimes be altered to different chemical phases before they reached a phase that would allow the nuclides to be released from the waste. Also, different radionuclides have different chemical properties, so the reaction rates of the individual nuclides with water would vary greatly. In general, however, modeling results show that once the waste form began to alter, it would take about 1,000 years for the commercial spent nuclear fuel to degrade completely in the case of the reference design repository. The result would be that certain nuclides would be released much earlier than others. The results of the long-term performance analysis show this effect, as different nuclides become the key contributors to dose rate over different time periods.

The *waste-form degradation* model uses degradation-rate formulas developed from experiments for the three different waste forms discussed in Section 5.1. This model provides values for the mass of the waste form exposed and the volume of water in contact with this waste form over time. These outputs are used to calculate the radionuclide release rate to the water inside the waste package. The rate at which a particular radionuclide would be released from the waste form would depend on the solubility of the radionuclide in the seepage water. Low-solubility radionuclides would tend to reach their solubility limit

quickly, so the waste form could release them at the rate at which the water carried them away. High-solubility radionuclides would be released at a rate that would depend on the rate at which the water reacted with the waste form. The Viability Assessment (DOE 1998a, Volume 3, page 3-99) contains a more detailed discussion of the waste degradation model. The solubilities and assumed mechanisms in the waste degradation models are based on the best available information, but there are differing opinions, particularly about mechanisms of release and solubility of specific radionuclides such as neptunium-237. These differing opinions deal with:

- The appropriate solubility for neptunium (DOE 1998o, all)
- Mobilization of radionuclides from the spent nuclear fuel through a vapor-phase release mechanism (DOE 1998o, page 7) (the current model assumes only a liquid-phase release mechanism)

The long-term performance modeling results show that neptunium-237 would be an important contributor to long-term health effects.

Either of these variations could result in a different rate of release than the current analysis estimated. Higher neptunium solubility could result in higher release rates because solubility determines the release rate of neptunium in the current model. However, the long package life in the current system (modeling results show only a few packages would fail before 10,000 years) would tend to reduce any effect of differences in release rates prior to 10,000 years after closure, should any of these alternative interpretations prove to be accurate. In the model results, package failure rates versus time dominate the dose rates such that the release rate after package failure would play a minor role in determining total dose over time. In the 1-million-year period after closure, there could be some change in dose rates. The addition of vapor processes to aqueous transport processes could increase estimated dose rates by an undetermined amount. DOE is planning additional studies that will help deal with these issues (DOE 1998a, Volume 4, page 3-19).

To move out of the waste package, the radionuclides either would be carried away from the waste form in flowing water or would move in a thin film of water by diffusion. To escape, the radionuclides would have to exit through a pit or patch in the waste package and move out into the waste emplacement drift. The *radionuclide-mobilization and engineered-barrier system transport* model uses the seepage flux and radionuclide solubility in the groundwater to calculate the amount of each radionuclide that would move into the unsaturated zone (DOE 1998a, Volume 3, pages 3-90 to 3-109). It passes the amount of each radionuclides released directly to the unsaturated zone transport model.

5.2.3.4 Reduction in Concentration of Radionuclides and Chemically Toxic Materials During Transport

After escaping from the waste package, the radionuclides and other nonradioactive materials could advance through materials on the drift floor, which would be mainly concrete, and the corrosion products from the waste package. At this point, the radionuclides could either adhere to some of the materials on the drift floor, continue moving in the water, or become attached to extremely small particles of clay, silica, or iron called "colloids." Because of their molecular charge and physical size, these colloidal particles would move through the rock mass under the proposed repository somewhat differently than noncolloidal particles.

The radionuclides and chemically toxic materials would move down beneath the proposed repository at different rates based on (1) the chemical characteristics of the contaminants and of the rock they would be passing through and (2) the velocity of the water in which they were contained. The rock underlying the repository is unsaturated, and the water movement behaves as described above. Some water moves rapidly in fractures and some much more slowly in the rock. The transport rate would also depend on the

tendency of the individual radionuclide or chemical to interact with the rock through which it would move. Some radionuclides would adhere to some minerals in a process called *sorption* and would be bound in the rock for long periods. Sorption can be irreversible in some instances, leaving the nuclide bound permanently in the rock. In other cases, the radionuclides could desorb at a future time and move through the rock. Other types of radionuclides would move more quickly through the rock with little or no interaction that delayed their transport. The analysis assumed that the nonradioactive toxic chemicals would not sorb and would move at the same rate as the water. This conservative assumption was based on a lack of reliable data on the sorption of these materials on tuff. The three-dimensional *unsaturated zone transport* model calculated the amount of each radionuclide and nonradioactive chemical species that would move from the unsaturated zone into the saturated zone and passed this value to the saturated zone transport model (DOE 1998a, Volume 3, pages 3-109 to 3-129).

When the radionuclides reached the water table, they would be caught in the saturated zone flow system. Beneath Yucca Mountain, the water in the saturated zone flows in a generally southerly direction toward the Amargosa Valley. Nuclide sorption would also occur in the rocks and alluvium along the flow paths in the saturated zone. Because of the differences in chemistry between the unsaturated and saturated zone rock and water, the transportation rates of nuclides involved in sorption would be different for the two zones. As the radionuclides moved in the saturated zone along different paths and through different materials, they would gradually become more dispersed and the concentration of the nuclides in any volume of water would decrease.

The *saturated zone transport* model calculates the movement of radionuclides from the unsaturated zone through an aquifer to a groundwater well or surface discharge location. This model is based on the assumption that water in the saturated zone travels along six paths or stream tubes between Yucca Mountain and the well (DOE 1998a, Volume 3, pages 3-130 to 3-143). This six-stream-tube model does not model dilution in the saturated zone; rather, a dilution factor recommended in an expert elicitation exercise (DOE 1998a, Volume 3, page 3-138) was applied to the results for 20 kilometers (12 miles). The basic recommended dilution factor was supplemented by additional empirical calculations for the distances and repository layouts in this EIS. Appendix I, Section I.4.5.4, of this EIS discusses these additional dilution factors. The model performs these flow and transport simulations for nine radionuclides and three chemically toxic materials using multiple simulations of uncertain saturated zone model parameters.

If the radionuclides were removed from the saturated zone by water pumped from wells, the radioactive material could cause doses to humans in several ways. For example, the well water could irrigate crops that persons or livestock consumed, water stock animals that provided milk or meat products, or provide drinking water. In addition, if the water pumped from irrigation wells evaporated on the ground surface, the nuclides could be left as fine particulate matter that could be picked up by the wind and inhaled by humans. The *biosphere* pathway model (DOE 1998a, Volume 3, pages 3-145 to 3-162) addresses what would happen to radionuclides between the time they were pumped from a well and the time they were ingested by a human being. The model uses a biosphere dose-conversion factor that converts saturated zone radionuclide concentrations to individual radiation dose rates. The dose factor was developed by analyzing the multiple pathways through the biosphere by which radionuclides can affect a person. The biosphere scenario assumed a reference person living in the Amargosa Valley region at various distances from the proposed repository at Yucca Mountain. People living in the community of Amargosa Valley would be the group most likely to be affected by radioactive releases (the critical group) because of their proximity to the proposed repository, and because the Amargosa Valley region is hydraulically downgradient from the proposed repository (Luckey et al. 1996, page 14). The reference person is representative of this group: an adult who lives year-round at this location, uses a well as the primary water source, and otherwise has habits (such as the consumption of local foods) similar to those of the

inhabitants of the region. Because changes in human activities over millennia are unpredictable, the analysis assumed that the present-day reference person described future inhabitants.

The chemically toxic materials are not evaluated in the biosphere model because there are no usable dose comparison values. Instead, the concentrations of these materials in the groundwater are reported at the same distances where the radionuclide doses were evaluated. The concentrations are then compared to available regulatory standards such as the Maximum Contaminant Level Goal.

The groundwater analysis described above does not consider an alternative view of possible important groundwater migration mechanisms. In 1989, J. S. Szymanski (then a DOE staff scientist) raised the possibility of inundation of the proposed repository as an issue in a report to DOE (Szymanski 1989, all). This view is discussed in detail in Chapter 3, Section 3.1.4.2.2, and DOE does not agree with the inundation scenario for the reasons discussed in Chapter 3. There has been no analysis to determine the effects; however, if such an event occurred, the long-term impacts would probably increase greatly.

The groundwater path doses are based on specific paths of groundwater flow derived from regional data. There are differing opinions about these flow paths, which are derived from regional hydraulic head data and other measurements (Lehman and Brown 1996, all). This alternative concept of flow interprets local high pressure to be due to features such as faults and concludes with a largely different flow pattern in the 20-kilometer (about 12-mile) radius around the proposed repository. These alternative paths could produce somewhat different results in the saturated zone groundwater travel rates, direction, and dilution factors. Such changes could have some effect on the dose estimates. DOE does not know whether adaptation of the alternative paths would increase or decrease dose or how large an effect there would be. The current design of the proposed repository relies very heavily on the delay of release by providing long-lived waste packages, such that package failures would occur periodically over hundreds of thousands of years. The long lives of the packages tend to control the dose results, especially because the saturated zone delay and mixing has a small effect on the concentrations exiting the proposed repository. Therefore, alternative flow paths would not be likely to have a large effect on doses.

5.2.3.5 Disruptive Events

The key attributes of the system, given in the previous sections, describe the continually ongoing processes expected to occur in and around the proposed repository system. The term used to denote the sequence of anticipated conditions is the "nominal case." In contrast, the "disturbed case" refers to discrete, unanticipated events that disrupt the nominal case system. The disruptive events include the following (with impacts discussed in Section 5.7):

- Formation of a volcano in or near the proposed repository
- Earthquake
- Human intrusion into the proposed repository

Yucca Mountain is in a terrain that has experienced volcanic activity in the geologic past. The rocks in which the repository would be constructed are volcanic in origin. However, scientific studies of

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Features are physical parts of the system important to how the system could perform. Examples include the Ghost Dance Fault and the Topopah Spring stratigraphic unit.

Events are occurrences in time that can affect the performance or behavior of the system. Events tend to happen in short periods in comparison to the period of concern, and they tend to occur at unpredictable times. Examples include a volcanic intrusion or a human intrusion by drilling.

Processes are physical and chemical changes that occur over long periods, tend to be 100-percent likely to occur, and are predictable. Examples include corrosion of the metals in the waste package and dissolving of waste form materials after exposure to water.

the timing, volume, and other aspects of volcanism have concluded that volcanic activity in this area has been waning in the recent geologic past and that the probability of volcanic activity as a repository-disturbing event is low. For completeness, part of the long-term performance analysis is an assessment of the consequences of a small cinder cone formed by a dike (a lava flow) that flowed up through or close to the proposed repository drifts.

In contrast, earthquakes have occurred in the Yucca Mountain geologic region of influence, and are likely to occur in the future. The effects of an earthquake that would be important to postclosure repository performance primarily would result from ground motions rather than from direct offset along a fault, because the waste emplacement areas would be away from block-bounding faults, which are the most likely sites for fault offsets. The primary effect of ground shaking would be to hasten rock fall into the drift. Such rock fall would have the potential to damage the waste package and hasten water intrusion into the waste form.

The analysis treated human intrusion as an event in which part of the contents of a waste package would be released to the water table through the borehole of a well drilled directly through the proposed repository. Providing a verifiable forecast of future human activity is very difficult, if not impossible. The impact of such human intrusion was not included directly in the final presentation of results but was compared to the long-term performance results to determine the potential level of influence. In other words, the probability of human intrusion occurring was not modeled; however, the possible consequences were qualitatively evaluated for a few intrusion scenarios.

5.2.3.6 Nuclear Criticality

A nuclear criticality occurs when sufficient quantities of fissionable materials come together in a precise manner and the required conditions exist to start and sustain a nuclear chain reaction. The waste packages would be designed to prevent a criticality from occurring in one of them. In addition, it is very unlikely that a sufficient quantity of fissionable materials could accumulate outside the waste packages in the precise configuration and with the required conditions to create a criticality. If, somehow, an external criticality were to occur, analyses indicate that it would have only minor effects on repository performance. An explosive criticality is not credible (DOE 1998a, Volume 3, pages 4-92 to 4-99).

5.2.3.7 Atmospheric Radiological Consequences

In addition to the groundwater pathway, the long-term performance analysis evaluated the potential consequences of the release of radioactive gases into the environment. An analysis separate from the groundwater modeling described in the previous sections was used to forecast such consequences. The model used results from the waste-package degradation models to evaluate when packages and fuel cladding would fail and therefore release contained radioactive gases. This model provided input to release and transport estimates for the atmospheric pathway. Section 5.5 contains details of this analysis.

5.2.4 UNCERTAINTY

As with any impact estimate, there is a level of uncertainty associated with the forecast, especially when estimating impacts over thousands of years. *Uncertainty* can be defined as the measure of confidence in the forecast related to determining how a system will operate or respond. The amount of uncertainty associated with an impact estimate is a reflection of several factors, including the following four:

- An understanding of the components of a system (such as human and societal, hydrogeologic, or engineered) and how those components interact. The greater the number of components, the more complex the system, or the lesser capability to measure or understand the system or components

produces a greater potential for uncertainty. Similarly, fewer studies or more assumptions produce greater potential for uncertainty.

- The time scale over which estimates are made. Longer time scales for forecasts produce greater potential for uncertainty.

- The available computation and modeling tools. More general computation tools or more assumptions produce greater potential for uncertainty.

- The stability and uniformity (or variability) of the components and system being evaluated. Less stability and uniformity (that is, greater variability) produces a greater potential for uncertainty.

DOE recognizes that uncertainties exist from the onset of an analysis; however, forecasts are valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available. The following section discusses uncertainties in the context of possible effects on the impact estimates reported in this chapter. The discussion is divided to address:

- Uncertainty associated with societal changes and climate
- Uncertainty associated with currently unavailable data
- Uncertainty associated with models and model parameters

5.2.4.1 Uncertainty Associated with Societal Changes, Climate, and Other Long-Term Phenomena

General guidance on predicting the evolution of society has been provided by the National Academy of Sciences. In its report, *Technical Bases for Yucca Mountain Standards* (National Research Council 1995, all), the Committee on Technical Bases for Yucca Mountain Standards concluded that there is no scientific basis for predicting future human behavior. The study recommends policy decisions that specify the use of default (or reference) scenarios to incorporate future human behaviors in compliance assessment calculations. The analysis in this chapter follows the recommended approach, using as defaults societal conditions as they exist today; as such, it is based on the assumption that populations would remain at their present locations and population densities would remain at their current levels. However, this assumption, while appropriate for estimating impacts for comparison with other proposed actions, is not realistic because it is likely that populations will move and change in size. For example, if populations were to move closer to or increase in size in the Yucca Mountain groundwater hydrology region of influence, the radiation dose and resultant impacts could increase. DOE does not have the means to predict such changes quantitatively with great accuracy; therefore, the analysis does not attempt to quantify the resultant effects on overall impacts. In addition, the analysis does not address the potential benefits from future human activities including improved technology for removing radioactive materials from drinking water or the environment or medical advances such as cures for cancer.

Estimates of future climatic conditions are based on what is known about the past, with consideration given to climate impacts caused by human activities. Calcite in Devils Hole, a fissure in the ground approximately 40 kilometers (25 miles) southeast of Yucca Mountain, provides the best dated record of climate changes over the past 500,000 years. The record shows continual variation, often with very rapid jumps, between cold glacial climates (for the Great Basin, these are called pluvial periods) and warm interglacial climates similar to the present. Fluctuations average 100,000 years in length. Because this basic time scale has been corroborated by other measurements (for example, oxygen-isotope variations in marine sediments), it has been selected as the average climate cycle (DOE 1998a, Volume 3, page 3-8). The past climate cycles were then idealized into a regular cycle of pulses, which were repeated throughout the period of the forecast. This method inherently assumes that the future will repeat the past.

However, while current understanding of the causes of climate change allows some confidence in this approach, a considerable amount of conservatism was built into the models to account for possible climate uncertainties. For example, a large range of water fluxes were used to reflect the wide rainfall variations that could occur over thousands and hundreds of thousands of years. The analysis assumed that the current climate is the driest it will ever be at Yucca Mountain.

5.2.4.2 Uncertainty Associated with Currently Unavailable Data

DOE is planning additional work to help reduce the amount of uncertainty associated with currently unavailable data. The supporting models will be updated to address the principal factors that have been made a high priority in the DOE plan (DOE 1998a, Volume 4, page 2-29). These factors include:

- Drift seepage and percolation to depth
- Effects of heat and excavation on flow
- Dripping onto waste packages
- Chemistry of water on the waste packages
- Integrity of the inner corrosion-resistant waste package barrier
- Integrity of the spent nuclear fuel cladding
- Formation and transport of radionuclide-bearing colloids
- Transport in the unsaturated zone

The planned work in these areas is summarized below. More detailed information about this work and other planned work to address principal factors with lower priority is provided in the technical work plan (DOE 1998a, Volume 4, page 3-1 to 3-58).

Data on percolation and seepage at the drift scale will continue to provide insights on the processes that will control the amount of water that might contact waste packages. Planned work will examine percolation over that part of the proposed repository layout accessed by the cross drift and in geologic layers that will include more of the repository horizon. Plans include the following testing and modeling activities:

- *Excavation of two additional niches and preparation of two fracture/matrix test beds in the cross drift.* Seepage and fracture/matrix interaction tests will be performed in the lower Topopah Spring units that comprise the majority of the potential repository horizon. Planned tests include liquid release tests and long-term tracer injection tests.

- *Perform additional geochemical and isotopic analyses to determine where water has flowed in the past.* Concentrations of chemical components in the rock such as chloride, bromide, and sulfate will be measured, and the results will be used to identify fast paths and travel times. Ongoing analyses of the isotopic ages of fracture-lining minerals will provide information on the history of water movement. These studies show how and when water has moved through the unsaturated zone and reveal characteristics of the water, such as the chemical composition and temperature.

- *Perform a controlled study of percolation from the cross drift to the underlying Exploratory Studies Facility main drift.* The cross drift infiltration experiment in the crossover alcove will provide data on percolation rates through fractured welded tuffs under controlled boundary conditions.

- *Monitor moisture conditions in the Exploratory Studies Facility, including the cross drift.* Moisture monitoring activities in Alcoves 1 and 7 of the Exploratory Studies Facility will continue and

monitoring in the cross drift will be established, for the study of moisture balance, ventilation effects, and the movement of water used in construction.

- *Update percolation and seepage models.* Percolation processes have been modeled at two scales: mountain and drift. These models will be updated so the modeled hydrostratigraphy is consistent with recent laboratory and field test data. Models for seepage into drifts will also be updated to encompass field test data and the effects of thermally driven-coupled processes.

The effects of heating on seepage are being investigated in a drift-scale thermal test currently being conducted and by laboratory experiments that will support models for predicting the effects of coupled processes over much longer periods.

5.2.4.3 Uncertainty Associated with Models and Model Parameters

The total system performance model used to assess the impacts from groundwater migration includes a very large number of submodels and requires a large amount of input data to estimate the performance of the system. The model must account for important features of the system, likely events, and processes that would contribute to the release and migration of materials. Because of the long periods simulated, the complexity and variability of a natural system, and several other factors, the performance modeling must deal with a large degree of uncertainty. This section discusses the nature of the uncertainties and how they were accounted for in the analysis and their implication to interpretation of impact results. The *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a, Volume 3, pages 4-63 to 4-71) contains further details concerning this subject.

5.2.4.3.1 *Variability Versus Uncertainty*

A variable feature, event, or process is one that changes over space or time. Examples include the porosity of the rock mass, the temperature in the repository, and the geochemical environment in the repository drifts. If all information was available, such parameters would be best expressed as known mathematical functions of space and time. In contrast, uncertainty relates to a lack of knowledge regarding a feature, event, or process—one whose properties or future outcome cannot be predicted. Four types of uncertainty are typically considered: value uncertainty, conceptual model uncertainty, numerical model uncertainty, and uncertainty regarding future events. The treatment of a feature, event, or process as purely variable or purely uncertain can lead to different modeling results.

Uncertainty and variability are sometimes related. The exact nature of the variability in a natural system cannot be known because all parts of the system cannot be observed. For example, DOE cannot dig up all the rock in Yucca Mountain and determine that the positioning of the rock layers is exactly as suggested by core sample data. Therefore, there is uncertainty about the properties of the rock at specific locations in the mountain because properties change with distance and it is not known how much they change at any given location. If the variability can be appropriately quantified or measured, a model usually can be developed to include this variability. If the variability cannot be physically quantified or estimated, it should be treated as uncertainty (lack of knowledge). However, the ability to model some types of spatial variability can be limited not only by lack of data but also by the capacity of a computer to complete calculations (for example, if one simulation took weeks or months to complete). In these instances, variability must be simplified in such a way as to be conservative (that is, the simulation would overestimate the impact).

Two basic tools were used in the analysis to deal with uncertainty and variability: alternative conceptual models and probability theory. Alternative conceptual models were used to handle uncertainty in the understanding of a key physical-chemical process controlling system behavior. Probability theory was

used to understand the impacts of uncertainty in specific model parameters (that is, would results change if the parameter value was different). In particular, uncertain processes often required different conceptual models. For example, different conceptual models of how water in fractures communicates with water in the smaller pores or the matrix of the rock in the unsaturated zone lead to different flow and transport models. Sometimes conceptual models are not mutually exclusive (for example, both matrix and fracture flow might occur), and sometimes they do not exhaustively cover all possibilities (apparently matrix and fracture flow do cover all possibilities). These examples indicate that the use of alternative conceptual models, while often necessary to characterize some types of uncertainty, is not always as exact as desired.

A process of weighting alternative conceptual models (as described below) was used in the long-term performance assessment to account for uncertainties in conceptual models. The *Monte Carlo* sampling technique was used for handling uncertainty in specific model parameters and for alternative conceptual models that were weighted beforehand with specific probabilities. The method involves random sampling of ranges of likely values, or *distributions*, for all uncertain input parameters. Distributions describe the probability of a particular value in the range. A common type of distribution is the familiar "bell-shaped" curve, also known as *normal distribution*. Parameters in the system performance analysis are described by many different types of distributions appropriate for how the values and their probabilities are understood. Numerous realizations of the repository system behavior were calculated, each based on one set of samples of all the inputs. Each total system realization had an associated probability so that there is some perspective on the likelihood of that set of circumstances occurring. The Monte Carlo method yields a range for any chosen performance measure (for example, peak dose rate to an individual in a given period at a given location) along with a probability for each value in the range. In other words, it gives an estimate of repository performance and determines the possible errors based on the estimate. In this chapter, the impact estimates are expressed as the mean of all the realizations and the 95th-percentile value (that is, the value for which 95 percent of the results were smaller).

5.2.4.3.2 *Weighting of Alternative Conceptual Models*

In some cases, modeling alternatives form a continuum, and sampling from the continuum of assumptions fits naturally in the Monte Carlo framework of sampling from probability distributions. In other cases, the assumptions or models are discrete choices. In particular, some processes are so highly uncertain that there are not enough data to justify developing continuous probability distributions over the postulated ranges of behavior. In such cases, a high degree of sampling is unwarranted, and an analysis often models two or three cases that it assumes to encompass (bound) the likely behavior.

There were two possible approaches to incorporating discrete alternative models in the performance assessment: weighting all models into one comprehensive Monte Carlo simulation (lumping), or keeping the discrete models separate and performing multiple Monte Carlo simulations for each discrete model (splitting). In this analysis, a combination of the two approaches was used. The main results in Section 5.4 were developed using the splitting approach because they were based on a limited range of uncertainty. Based on expert judgment (and to some extent the finite time and resources that could be applied to the analysis effort), the analysis used a best estimate of the more likely ranges of model behavior and parameter ranges. Some alternative models were not included in the analysis, and some parameter ranges of the included models were narrowed. The level of uncertainty included in the model was based on the current level of knowledge regarding the various processes controlling system behavior. In several instances, the range of uncertainty was set quite large, in a conservative manner. Because of this narrowed range of models and parameters, the results are *conditional*, meaning that they depend on certain models and parameters being held constant or having their variance restricted. One such condition is the specific design of the repository and the waste packages in the reference design of this EIS. Another important condition is that the cladding on the spent nuclear fuel can be depended on as a barrier.

Other conditional results were used to characterize the effect of certain assumptions. For example, results are given in this chapter for three thermal load scenarios; Section 5.4.4 describes the result when the fuel cladding was not considered as a barrier. Additional splitting was done to consider such events as human intrusion (Section 5.7.1), volcanic disturbances (Section 5.7.2), and seismic disturbances (Section 5.7.3). The consequences of these types of events are not part of results given in Section 5.4, rather they are reported as added impacts with certain probabilities of occurrence.

5.2.4.3.3 *Uncertainty and the Proposed Action*

The analysis for the Proposed Action encompassed many of the underlying uncertainties. It included some of all four types of uncertainty: value or parameter uncertainty, conceptual model uncertainty, numerical model uncertainty, and future-event uncertainty. Therefore, the results represent a "lumping" approach. Uncertainty not lumped into the modeling, which produced the central results in Section 5.4, was addressed discretely in alternative models, alternative features, and alternative events such as human intrusion. These alternatives were "split" from the nominal results, and their effects on performance are described separately.

5.2.4.3.4 *Uncertainty and Sensitivity*

In addition to accounting for the uncertainty, characteristics of the engineered and natural systems (such as the unsaturated and saturated zones of the groundwater system) that would have the most influence on repository performance also need to be understood. This information helps define *uncertainty* in the context of what would most influence the results. This concept is called *sensitivity analysis.* A number of methods are used to explain the results and quantify sensitivities. Total system performance is a function of sensitivity (if a parameter is varied, how much do the performance measures change) and uncertainty (how much variation of a parameter is reasonable). For example, the long-term performance results could be very sensitive to a certain parameter, but the value for the parameter is exactly known. In the uncertainty analysis techniques described below, that parameter would not be regarded as important. However, many parameters in the analyses do have an associated uncertainty and do become highly important to performance. On the other hand, the level of their ranking can depend on the width of the assigned uncertainty range.

Most of the important parameters with possibly limited uncertainty ranges in the model were examined in alternative models. The alternative models either expand the range of the parameters beyond the expected range of uncertainty or change the weighting of the parameter distribution. For example, this type of analysis was performed for alternative models of seepage (DOE 1998a, Volume 3, pages 5-1 to 5-9) and cladding degradation (DOE 1998a, Volume 3, pages 5-32 to 5-35).

System performance could be sensitive to repository design options, but models and parameters for these various options do not have an assigned uncertainty. Therefore, although they can be important, they do not show up as key parameters based on uncertainty analysis. The determination of the parameters or components that are most important depends on the particular performance measure being used. This point was demonstrated in the 1993 Total System Performance Assessment (Andrews, Dale, and McNeish 1994, all; Wilson et al. 1994, all) and the *Total System Performance Assessment–1995* (TRW 1995b, all). For example, these two analyses showed that the important parameters would be different for 10,000-year peak doses than for 1-million-year peak doses.

There are several techniques for analyzing uncertainties, including the use of qualitative scatter plots where the results (for example, dose rate) are plotted against the input parameters and visually inspected for trends. In addition, performance measures can be plotted against various subsystem outputs or surrogate performance measures (for example, waste package lifetime) to determine if that subsystem or

performance surrogate would be important to performance. There are several formal mathematical techniques for analyzing the sets of realizations from a Monte Carlo analysis to extract information about the effects of parameters. Such an analysis determined the principal factors affecting the performance of the reference design.

5.2.4.3.5 *Confidence in the Long-Term Performance Estimates*

As described above, the analysis accounted for the many uncertainties involved. Further, an understanding of the sensitivities of principal factors in the system performance was developed. Table 5-3 lists the principal factors as they relate to repository performance, and relates the factors to model confidence and significance of uncertainty (sensitivity). If there is low confidence in the model (high uncertainty) and high significance, planned research will further refine the model and data (DOE 1998a, Volume 4, Section 3). For example, ongoing research emphasizes transport through the unsaturated zone and the integrity of the inner corrosion-resistant waste package barrier.

Table 5-3. Confidence in the long-term performance of the repository system in relation to groundwater contamination.[a]

Desired attributes of the repository and principal factors associated with the reference design	Confidence in the models to reasonably represent the impacts and processes	Significance of uncertainty to the estimate of performance
Limited water contacting waste package		
Precipitation and infiltration of water into the mountain	High	Medium
Percolation to depth	Medium	Medium
Seepage into drifts	Low	High
Effects of heat and excavation on flow	Low	Medium
Dripping onto waste package	Low	Medium
Humidity and temperature at waste package	Very High	Low
Long waste package lifetime		
Chemistry at waste package	Medium	Medium
Integrity of outer waste package barrier	High	Medium
Integrity of inner waste package barrier	Medium	High
Low rate of release of radionuclides from breached waste package		
Seepage into waste package	Medium	Medium
Integrity of spent fuel cladding	Medium	High
Dissolution of uranium oxide and glass waste form	High	Medium
Solubility of neptunium-237	High	Medium
Formation of radionuclide- bearing colloids	Low	Medium
Transport of radionuclides within and out of waste package	Medium	Medium
Radionuclide concentration reduction during transport between the waste package and the environment		
Transport of radionuclides through the unsaturated zone	Low	High
Transport of radionuclides through the saturated zone	Low	Medium
Dilution from pumping in water supply	Very High	Medium
Biosphere transport and uptake	Very High	Low

a. Source: Adapted from DOE (1998a, Volume 4, Table 2-2, page 2-20).

The general approach to long-term performance analysis in this EIS conforms with international practices, as assured through continued participation in the Performance Assessment Advisory Group of the Nuclear Energy Agency of the Organization for Economic Cooperation and Development in Paris. The Performance Assessment Advisory Group has had the Yucca Mountain Site Characterization Project as a contributing and participating member for many years, and the group has fostered the open discussion of current performance assessment approaches across national boundaries and regulatory boundaries. This practice has allowed the critical evaluation of member nations' performance assessment approaches. A document produced by this group compared more than 10 recent performance assessments, in terms of

approach and scope, and made recommendations for the general content of a safety evaluation (OECD 1997, all). This information is being considered in the planning, production, and documentation of ongoing performance assessment work.

In addition, the long-term performance analysis approach in this EIS is generally accepted by the external oversight and internal review groups, including the Nuclear Waste Technical Review Board and the Total System Performance Assessment Peer Review Panel. Nevertheless, these two groups have criticized specific elements of the performance assessment work represented in this EIS, and they have made recommendations in several reports for additional work to support the modeling.

For example, the most recent report of the Total System Performance Assessment Peer Review Panel states that "the overall performance assessment framework and the approach used in developing the TSPA-VA were sound and followed accepted methods," but also includes approximately 145 pages of observations and suggestions for improvements. All of the suggestions are being addressed in the overall planning for the Site Recommendation of 2001 and, if the site is approved, the License Application of 2002. Volume 4 of the Viability Assessment (DOE 1998a, Volume 4, pages 3-1 to 3-68) discusses this planning. The Panel was particularly critical when stating that the report failed to provide a statement of the "probable behavior of the repository" as requested by Congress. The Panel interpreted that requirement to be an impossibly exacting test. The Panel suggested that the Department should move away from seeking predictive certainty and show safety through bounding arguments and conservative designs, as is done in this EIS. The Department, in the context of preparing a performance evaluation that provides for a "reasonable assurance" of safety, generally agrees with the Panel's advice.

The EIS performance assessment represents a "snapshot in time" and ongoing work will help refine that snapshot. In the meantime, DOE believes the performance results of this EIS are conservative estimates, and that work currently in progress or planned will increase confidence in the overall modeling approach.

5.3 Locations for Impact Estimates

Yucca Mountain is in southern Nevada, in the transition area between the Mojave Desert and the Great Basin. It is a semiarid region with linear mountain ranges and intervening valleys, with current rainfall averaging between about 100 and 250 millimeters (4 and 10 inches) a year, sparse vegetation, and a low population. Although there is low infiltration of water through the mountain and no people currently live in the analyzed land withdrawal area, radioactive and chemically toxic materials released from the repository could affect persons living closer to the proposed repository in the distant future. This section describes the regions where possible human health impacts could occur.

Figure 5-3 is a map with arrows showing the general direction of groundwater movement from Yucca Mountain. Shading indicates major areas of groundwater discharge through a combination of springs and evapotranspiration by plants. The general path of water that infiltrates through Yucca Mountain is south toward Lathrop Wells, into and through the area around Death Valley Junction in the lower Amargosa Valley. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa (Czarnecki 1990, pages 1 to 12), and spring discharge in Death Valley is a possibility (D'Agnese et al. 1997, pages 64 and 69). Although groundwater from the Yucca Mountain vicinity flows near or under Ash Meadows in the volcanic tuff or alluvial aquifers, the surface discharge areas at Ash Meadows and Devils Hole are fed from the carbonate aquifer. While these two aquifers are connected, the carbonate aquifer has a hydraulic head that is 36 meters (120 feet) higher than that of the volcanic or alluvial aquifers. Because of this pressure difference, water from the volcanic aquifer does not flow into the carbonate aquifer; rather, the reverse occurs. Therefore, no contamination from Yucca Mountain could discharge to the surface at Ash Meadows or Devils Hole (TRW 1999h, all). Therefore, radionuclides released from a repository at Yucca Mountain would not appear in the surface discharge at

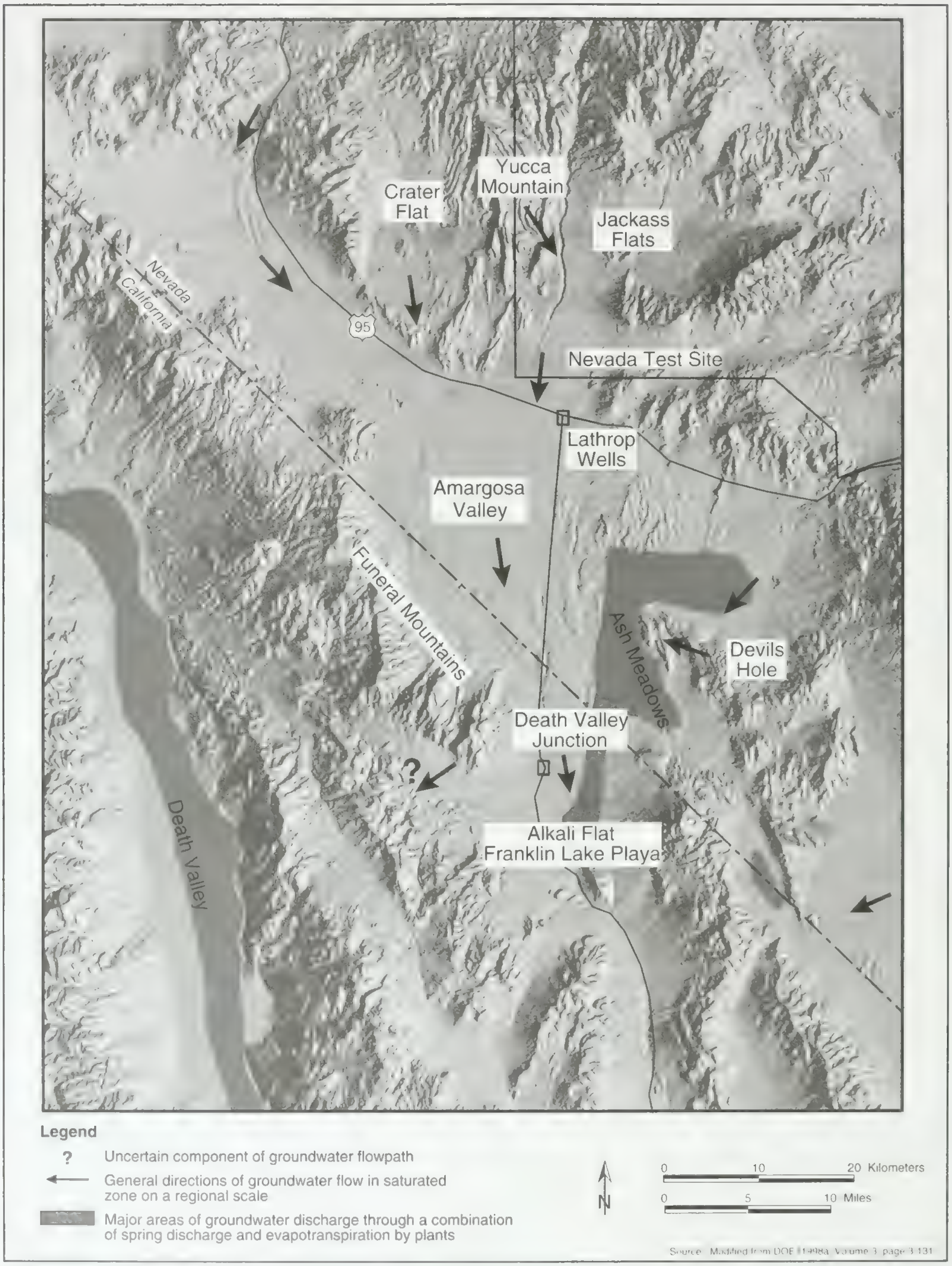


Figure 5-3. Map of the saturated groundwater flow system.

Ash Meadows or Devils Hole. Because there would be no contamination of this discharge water, there would be no human health impacts. Furthermore, there would be no consequences to the endangered Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*) or Devils Hole pupfish (*Cyprinodon diabolis*) at those locations.

> **POPULATION DOSE AND FUTURE POPULATION SIZE**
>
> *Population dose* is a summation of the dose received by individuals in an exposed population (unit of measure is *person-rem*). The population dose depends on the number of people at different locations. If the number of people increases in the future, the population dose estimate would also increase.

Figure 3-21 in Chapter 3 shows the estimated population of 28,000 permanent residents within 80 kilometers (50 miles) of Yucca Mountain in 2000. This map provides the information used to estimate population doses from radionuclides released to the atmosphere from the repository. The atmosphere analysis used an 84-kilometer radius rather than the 80-kilometer (50-mile) radius described in Chapter 3 to include the population of Pahrump.

People who could be exposed in the future to groundwater-borne contaminants would live to the south of Yucca Mountain in the direction of groundwater flow. At present, there are no permanent residences within 5 kilometers (3 miles) to the south of the proposed repository. Groundwater depth is approximately 100 meters (330 feet) at 5 kilometers from Yucca Mountain. Closer to Yucca Mountain, groundwater is at depths greater than 200 meters (660 feet), which imposes economic constraints on agricultural uses of land (DOE 1998a, Volume 3, page 3-150). Population projections for 2000 indicate that the area within 5 kilometers of the proposed repository would remain unpopulated (see Chapter 3, Figure 3-21) (for further discussion on why 2000 population was used, see Section 5.2.4.1). However, because there are sources of potable groundwater, the analysis performed human health impact calculations for a hypothetical person living 5 kilometers south of the proposed repository who uses well water.

At present, very few people live within 20 kilometers (12 miles) to the south of the repository, but there is some land suitable for farming in that region. For example, about eight permanent residents live in the Lathrop Wells community. Therefore, the analysis performed human health impact calculations, based on human ingestion of groundwater from wells in the area, for a person living 20 kilometers south of the proposed repository. The nearest private property in the direction of groundwater flow from the repository site is at the Nevada Test Site boundary approximately 18 kilometers (11 miles) to the south. Environmental consequences at 18 kilometers would not be expected to differ substantially (about 10 percent) from those estimated at 20 kilometers. The closest population center in the Amargosa Valley is about 30 kilometers (19 miles) away. The analysis calculated human health impacts from well water contamination to persons living at that location. Groundwater carrying dissolved radionuclides from the Yucca Mountain Repository could emerge as surface water at Franklin Lake Playa. The analysis also calculated human health impacts from surface-water discharge to a hypothetical person living near Franklin Lake Playa and identified them as impacts at the 80-kilometer (50-mile) or discharge location.

5.4 Waterborne Radiological Consequences

The following sections report potential radiation dose rates, expressed in millirem per year, to an individual living south of Yucca Mountain and using groundwater (characterized as the maximally exposed individual). The analysis converted the dose rate to the probability of contracting a fatal cancer (referred to as a latent cancer fatality) due to exposure to radioactive materials in the water. In addition, the analysis calculated population doses in person-rem for two different periods: for the 70-year lifetime at the time of the peak dose during the first 10,000 years after repository closure, and integrated over the

first 10,000 years after repository closure. The analysis also converted the population dose to the expected number of latent cancer fatalities in the population. DOE based the analysis on the inventories discussed in Section 5.1. However, the analysis included the entire carbon-14 inventory of the commercial spent nuclear fuel as a solid in the groundwater release models. Actually, 2 percent of the carbon-14 exists as a gas in the fuel (see Section 5.5). Thus, the groundwater models slightly overestimate (by 2 percent) the potential impacts from carbon-14.

MAXIMALLY EXPOSED INDIVIDUAL

DOE has used *maximally exposed individual* in environmental impact statements to help describe potential radiological impacts to an individual member of the public. Its use follows established DOE National Environmental Policy Act guidance and precedents.

The broad definition of a maximally exposed individual is a hypothetical person who is exposed to environmental contaminants (for example, radiation) in such a way—by a combination of factors including location, lifestyle, dietary habits, and so on—that this individual would be the most highly exposed member of the public. The definition of maximally exposed individual for evaluating postclosure exposures from the groundwater pathway in this EIS is a subset of this broad definition, defined for a narrower set of exposure conditions. In this EIS, the maximally exposed individual is a hypothetical member of the group of adults that would live in the Amargosa Valley after repository closure (no earlier than 2118), with a characteristic range of lifestyle, food consumption, and groundwater usage patterns. More specifically, this individual would grow half of the foods that the individual would consume on the property, irrigate crops and water livestock using groundwater, and would also use groundwater as a drinking water source and to bathe and wash clothes. The EIS analyzed four maximally exposed individuals to represent impacts from use of groundwater at four distances from the repository: 5, 20, 30, and 80 kilometers (3, 12, 19, and 50 miles). The 80-kilometer distance is Franklin Lake Playa.

5.4.1 CONSEQUENCES FROM THE GROUNDWATER EXPOSURE PATHWAY FOR THE HIGH THERMAL LOAD SCENARIO

Four sets of 100 model simulations were run for the high thermal load scenario, one set for each of the four distances from Yucca Mountain. Each simulation used separate sets of sampled uncertainty parameters and generated a dose-rate profile for the 10,000 years following repository closure. Each simulation produced the maximum dose rate (in millirem per year) over the 10,000 years. Table 5-4 lists the mean and the 95th-percentile values of the set of 100 peak dose rates. The table lists the dose rate to the maximally exposed individual and the resultant probability of a latent cancer fatality for that individual. The distance of the receptor from the repository would have a large influence on the dose and the number of latent cancer fatalities.

Ninety-five percent of the calculated dose rates for the maximally exposed individual at 5 kilometers (3 miles) would be below 1.3 millirem per year and would have an associated lifetime probability of a latent fatal cancer of 0.000044. For comparison purposes, the background radiation level from environmental sources in the United States is

RADIATION MEASURES

The **millirem** is the unit of radiological dose reported in this analysis. *Milli* means one one-thousandth. A *rem* (Roentgen Equivalent in Man) is the amount of ionizing radiation required to produce the same biological effect in a person as 1 roentgen of high-penetration X-rays. A **roentgen** is a unit of measure of X-ray or gamma-ray radiation exposure discussed in terms of the amount of energy transferred to a unit mass of air. One roentgen corresponds to the absorption of 87.7 ergs (6.5×10^{-6} foot-pound) per gram of air.

approximately 300 millirem per year (NCRP 1987, page 14), corresponding to an individual lifetime probability of contracting a latent cancer fatality of about 0.001.

Population doses were calculated based on the dose rates in Table 5-4. The population size was based on the population numbers in Figure 3-21 in Chapter 3 of this EIS. For these calculations, the analysis assumed that no one would be exposed at 5 kilometers (3 miles); eight people would be exposed at about 20 kilometers (12 miles); 1,126 people would be exposed at about 30 kilometers (19 miles); and 13 people would be exposed at about 80 kilometers (50 miles). Thus, approximately 1,150 people would be exposed to contaminated groundwater. This stylized population dose analysis assumes that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (National Research Council 1995, all) because it is impossible to make accurate predictions of future lifestyles and residence locations.

Table 5-4. Consequences for a maximally exposed individual from groundwater releases of radionuclides during 10,000 years after repository closure for the high thermal load scenario.

	Mean consequence[b]		95th-percentile consequence[c]	
MEI[a]	Peak dose rate (millirem/year)[d]	Probability of an LCF[e]	Peak dose rate (millirem/year)[d]	Probability of an LCF
At 5 kilometers[f]	3.2×10^{-1}	1.1×10^{-5}	1.3	4.4×10^{-5}
At 20 kilometers	2.2×10^{-1}	7.6×10^{-6}	5.8×10^{-1}	2.0×10^{-5}
At 30 kilometers	1.2×10^{-1}	4.2×10^{-6}	2.8×10^{-1}	1.0×10^{-5}
At discharge location[g]	3.0×10^{-2}	1.1×10^{-6}	2.9×10^{-3}	1.0×10^{-7}

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
e. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).
f. To convert kilometers to miles, multiply by 0.62137.
g. 80 kilometers at Franklin Lake Playa.

Table 5-5 lists the population consequences associated with the results given in Table 5-4. The values in Table 5-5 include a scaling factor for water use. The performance assessment transport model calculated the dose rates for the maximally exposed individual assuming dissolved radionuclides would mix only in water that flowed through the unsaturated zone of Yucca Mountain with no further mixing in the saturated zone aquifer. Infiltration through the Yucca Mountain Repository accounts for only about 27,000 cubic meters (22 acre-feet) of water per year (see Appendix I, Section I.4.5.3). This compares to an annual water use in the Amargosa Valley of about 17.3 million cubic meters (14,000 acre-feet) (see Table 3-11). The analysis diluted the concentration of the nuclides in the 27,000 cubic meters of water throughout the 17.3 million cubic meters of water prior to calculating the population dose.

Table 5-5. Population consequences from groundwater releases of radionuclides during 10,000 years after repository closure for the high thermal load scenario.

	Mean consequence[a]		95th-percentile consequence[b]	
Case	Population dose (person-rem)	Population LCF[c]	Population dose (person-rem)	Population LCF
Peak 70-year lifetime	1.5×10^{-2}	7.5×10^{-6}	3.5×10^{-2}	1.8×10^{-5}
Integrated over 10,000 years	3.7×10^{-1}	1.8×10^{-4}	1.2	5.8×10^{-4}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
c. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).

The consequences listed in Table 5-4 are small because the analysis computed that most of the waste packages would last longer than 10,000 years. The inner layer of the waste package would have a very low corrosion rate, but there is a high degree of uncertainty in the value of the average corrosion rate. Model simulations estimated that some of the waste packages would fail within 10,000 years but some would last for more than 1 million years after repository closure. The analysis accounted for premature failures due to manufacturing defects or mishandling during emplacement. It assumed that these failures (called *juvenile failures*) would occur exactly 1,000 years after repository closure. Based on a study of industrial experience of manufacturing and handling (DOE 1998a, Volume 3, page 3-81), the estimated rate of juvenile failures would be very low. If juvenile failures did not occur, the mean consequences listed in Table 5-4 would decrease by about 2 percent, while the 95th-percentile consequences would be unchanged.

The radionuclides that would contribute the most to individual dose in 10,000 years would be iodine-129, technetium-99, and carbon-14 dissolved in groundwater. For example, the mean consequence at 30 kilometers (19 miles) has iodine-129 contributing 59 percent of the dose rate, technetium-99 contributing 36 percent, and carbon-14 contributing 4 percent. This analysis assumed that 2 percent of the carbon-14 migrated as gas in the form of carbon dioxide (see Section 5.5 for more details). The groundwater modeling conservatively ensures that all of the carbon-14 migrates into the water part.

The times that the peak dose rates listed in Table 5-4 would occur are close to 10,000 years and still would be less than 1.0 millirem per year (Figure 5-4). This indicates that the dose rate would be rising at the end of the 10,000-year simulation period. The peak doses before 10,000 years would be due to the relatively quick dissolution and transport of technetium-99, iodine-129, and carbon-14 from failed waste packages. Table 5-6 lists the same type of results as those in Table 5-4, but the timeframe is 1 million years after repository closure. A small fraction of the model simulations for the 80-kilometer (50-mile) distance have an increasing dose rate at the 1-million-year mark. The dose rates that would be increasing after 1 million years were usually among the smallest of the entire set of 100 results. The simulations were ended after 1 million years largely because further radioactive decay would decrease dose rates even for very long-lived radionuclides. The peak dose rate usually coincided with the occurrence of a wetter climate period.

Table 5-6. Maximally exposed individual doses from groundwater releases of radionuclides during 1 million years after repository closure for the high thermal load scenario.

	Mean[b]		95th-percentile[c]	
MEI[a]	Peak dose rate (millirem/year)	Time of peak (years)	Peak dose rate (millirem/year)	Time of peak (years)
At 5 kilometers[d]	1,400	792,000	9,100	320,000
At 20 kilometers	260	336,000	1,400	364,000
At 30 kilometers	150	418,000	820	416,000
At discharge location[e]	50	818,000	190	716,000

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. 80 kilometers at Franklin Lake Playa.

The radionuclides that would contribute the most to the peak dose rate in 1 million years would be neptunium-237 and plutonium-242. The mean dose at 30 kilometers (19 miles) showed neptunium-237 contributing 92 percent of the dose rate, plutonium-242 contributing 5 percent, plutonium-239 contributing 1 percent, and uranium-234 contributing 1 percent. The plutonium isotopes contributing to dose were due to colloidal transport of plutonium, not transport of plutonium as a dissolved element in

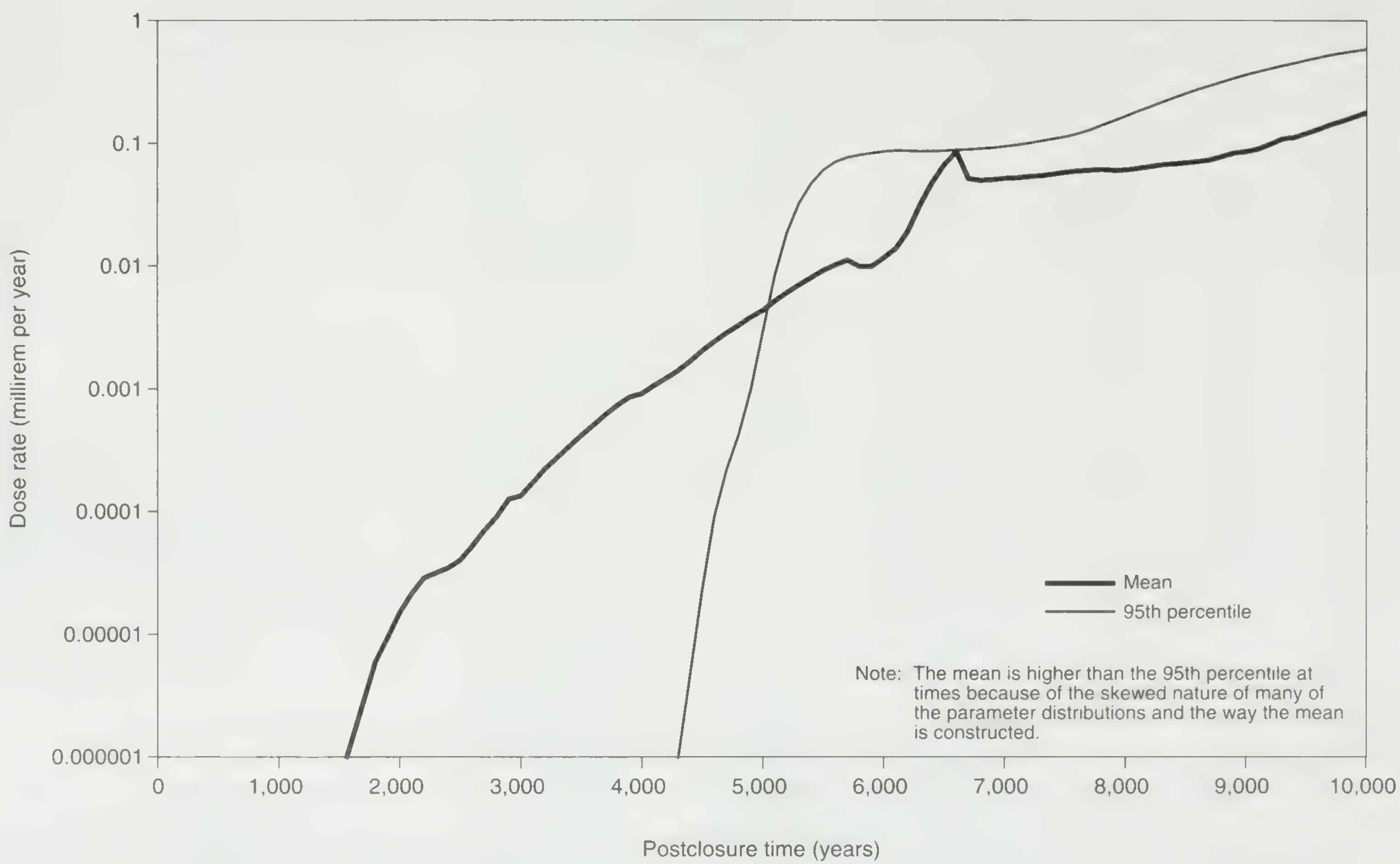


Figure 5-4. 10,000-year history of dose at 20 kilometers (12 miles) from the repository for the high thermal load scenario.

groundwater. In the construct of the mean, the time of occurrence of the peak dose can be very sensitive and might change abruptly to different times. This occurs because the time plot of the mean curve is relatively flat with occasional sudden peaks. Thus, the times of the peaks might not seem to be following a pattern. Since the mean does not represent any actual trial in the 100 simulations, the times of occurrence might not have much meaning. Similar effects will be noted in some of the results for the other thermal loads.

Table 5-7 lists peak radionuclide concentrations (amount of radionuclide in a volume of water) at four human exposure locations for the high thermal load scenario for the first 10,000 years after repository closure. It also lists the gross alpha-particle activity and the drinking water dose (the dose resulting from direct ingestion of the water at the given concentration). The gross alpha concentration is an analytical measurement used in monitoring the radiological quality of drinking water contamination levels. It represents the total amount of radioactivity from radionuclides with radioactivity due to the emission of alpha particles. (An alpha particle is a positively charged particle emitted by certain radioactive material, made up of two neutrons and two protons or the equivalent of a helium nuclei.) The consequences at each distance come from a different set of 100 simulations. As a result, some model predictions show fluctuations in the relative concentration of specific nuclides can occur at different distances. For example, the modeled concentration of carbon-14 for the 95th-percentile consequence would be higher at 30 kilometers (19 miles) than at 20 kilometers (12 miles), although the total modeled dose is about 2 times higher at 20 kilometers than at 30 kilometers (see Table 5-4).

Table 5-7. Peak radionuclide concentrations (picocuries per liter) in water and associated annual drinking water dose at human exposure distances for 10,000 years after repository closure for the high thermal load scenario.

	Mean consequence[a,b]				95th-percentile consequence[c]			
	Distance (kilometers)[d]				Distance (kilometers)			
Radionuclide	5	20	30	80	5	20	30	80
Carbon-14	2.1	1.1	6.4×10^{-1}	1.8×10^{-3}	8.2	1.8	3.1	2.7×10^{-2}
Iodine-129	1.3×10^{-1}	7.0×10^{-2}	4.1×10^{-2}	1.0×10^{-4}	5.7×10^{-1}	1.2×10^{-1}	2.0×10^{-1}	2.0×10^{-3}
Neptunium-237	6.4×10^{-4}	2.3×10^{-8}	6.1×10^{-15}	5.6×10^{-24}	6.5×10^{-4}	1.3×10^{-17}	1.3×10^{-23}	4.2×10^{-24}
Protactinium-231	2.9×10^{-12}	4.7×10^{-26}	4.7×10^{-26}	2.4×10^{-26}	2.0×10^{-24}	2.0×10^{-24}	1.3×10^{-26}	1.3×10^{-26}
Plutonium-239	5.7×10^{-5}	5.6×10^{-9}	4.8×10^{-10}	1.3×10^{-13}	1.8×10^{-9}	2.4×10^{-11}	8.1×10^{-10}	2.1×10^{-17}
Plutonium-242	3.5×10^{-7}	2.9×10^{-11}	3.1×10^{-12}	8.9×10^{-16}	1.0×10^{-11}	7.8×10^{-14}	4.5×10^{-12}	1.5×10^{-19}
Selenium-79	3.8×10^{-1}	8.2×10^{-4}	2.4×10^{-6}	1.4×10^{-21}	1.7×10^{0}	1.4×10^{-18}	6.8×10^{-19}	3.2×10^{-21}
Technetium-99	4.5×10^{1}	3.0×10^{1}	1.0×10^{1}	3.3×10^{-2}	3.9×10^{2}	8.4×10^{1}	1.3×10^{2}	8.3×10^{-1}
Uranium-234	8.8×10^{-5}	9.0×10^{-10}	1.2×10^{-16}	2.9×10^{-23}	8.3×10^{-5}	4.4×10^{-23}	3.7×10^{-23}	3.7×10^{-23}
Gross alpha[e]	7.0×10^{-4}	2.9×10^{-8}	4.8×10^{-10}	1.3×10^{-13}	6.5×10^{-4}	2.4×10^{-11}	8.1×10^{-10}	2.1×10^{-17}
Annual drinking water dose (millirem)	8.1×10^{-2}	4.8×10^{-2}	2.0×10^{-2}	5.9×10^{-5}	5.4×10^{-1}	1.2×10^{-1}	1.8×10^{-1}	1.3×10^{-3}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.

b. The concentrations for the mean and 95th-percentile consequences are the concentrations that yielded the mean and 95th-percentile doses reported in Table 5-4.

c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.

d. To convert kilometers to miles, multiply by 0.62137.

e. By regulatory convention, the gross alpha-particle radiation does not include uranium.

The annual drinking water doses in Table 5-7 (and below in Tables 5-11 and 5-15) are based on the assumption that an individual drinks exactly 2 liters (about 0.5 gallon) of water each day. Ingestion dose conversion factors were taken from Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion (Eckerman, Wolbarst, and Richardson 1988, pages 155 to 179). The full-pathway dose rates calculated in this chapter using biosphere dose

conversion factors were based on food and water intake values for a reference adult derived from an extensive survey of residents of the Amargosa Valley (DOE 1998a, Volume 3, pages 3-151 to 3-155).

Thus, the drinking water dose reported in Table 5-7 might be different from the portion of the total dose reported in Table 5-4 that is due to water consumption. For both the mean and 95th-percentile consequences, the gross alpha activity would be much lower than the 15 picocuries per liter specified as the attainment limit for drinking water for community water systems [40 CFR Part 141, Subpart B, Section 141.15(b)]. The dose rates from drinking liters (0.5 gallon) of water a day would also be below the 4-millirem-per-year limit for community water systems [40 CFR Part 141, Subpart B, Section 141.16(a)].

5.4.2 CONSEQUENCES FROM THE GROUNDWATER EXPOSURE PATHWAY FOR THE INTERMEDIATE THERMAL LOAD SCENARIO

Under the intermediate thermal load scenario, DOE would place the same inventory of materials in the repository as under the high thermal load scenario. This scenario would differ from the high thermal load scenario by increased spacing between the emplacement drifts. Thus, the radioactive and chemically hazardous material would be spread out over about 4.3 square kilometers (1,100 acres) rather than the approximately 3 square kilometers (740 acres) for the high thermal load scenario.

Table 5-8 lists the mean and 95th-percentile consequences of the set of 100 peak dose rates computed for this scenario. It also lists the dose to the maximally exposed individual and the resultant probability of a latent cancer fatality. The radionuclides contributing the most to the individual dose in 10,000 years would be technetium-99, iodine-129, and carbon-14. Figure 5-5 shows how peak dose increases over the first 10,000 years at the 20-kilometer (12-mile) distance and would remain below 1 millirem per year during this period.

Table 5-8. Consequences for a maximally exposed individual from groundwater releases of radionuclides during 10,000 years after repository closure for the intermediate thermal load scenario.

	Mean consequence[b]		95th-percentile consequence[c]	
MEI[a]	Peak dose rate (millirem/year)[d]	Probability of an LCF[e]	Peak dose rate (millirem/year)[d]	Probability of an LCF
At 5 kilometers[f]	1.4×10^{-1}	4.9×10^{-6}	1.1	3.9×10^{-5}
At 20 kilometers	1.3×10^{-1}	4.5×10^{-6}	5.8×10^{-1}	2.0×10^{-5}
At 30 kilometers	4.6×10^{-2}	1.6×10^{-6}	1.1×10^{-1}	3.9×10^{-6}
At discharge location[g]	2.9×10^{-3}	1.0×10^{-7}	1.9×10^{-3}	6.6×10^{-8}

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
e. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).
f. To convert kilometers to miles, multiply by 0.62137.
g. 80 kilometers at Franklin Lake Playa.

Table 5-9 lists the population consequences for the intermediate thermal load scenario. The scaling factor for changing the dose rate for the maximally exposed individual into a dose rate for a member of the population was computed by diluting the approximately 31,000 cubic meters (25 acre-feet) of water infiltrating through the Yucca Mountain Repository (see Appendix I, Section I.4.5.3) by the annual water use in the Amargosa Valley of about 17.3 million cubic meters (14,000 acre-feet).

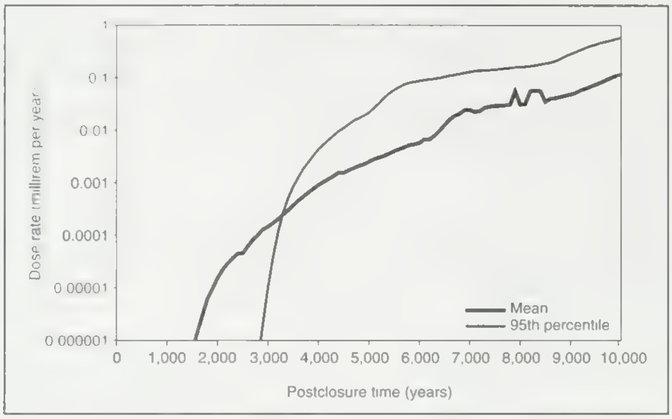


Figure 5-5. 10,000-year history of dose at 20 kilometers (12 miles) from the repository for the intermediate thermal load scenario.

Table 5-9. Population consequences from groundwater releases of radionuclides during 10,000 years after repository closure for the intermediate thermal load scenario.

Case	Mean consequence[a]		95th-percentile consequence[b]	
	Population dose (person-rem)	Population LCF[c]	Population dose (person-rem)	Population LCF
Peak 70-year lifetime	6.6×10^{-3}	3.3×10^{-6}	1.7×10^{-2}	8.3×10^{-6}
Integrated over 10,000 years	1.3×10^{-1}	6.7×10^{-5}	3.6×10^{-1}	1.8×10^{-4}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
c. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).

Table 5-10 lists results for peak consequences for the 1-million-year period. The radionuclides that would contribute the most to the peak dose rate would be neptunium-237 and plutonium-242. As with the 10,000-year case, there would be no meaningful trend due to thermal load in a comparison of this table to the similar table for higher thermal load scenarios.

Table 5-10. Maximally exposed individual doses from groundwater releases of radionuclides during 1 million years after repository closure for the intermediate thermal load scenario.

MEI[a]	Mean[b]		95th-percentile[c]	
	Peak dose rate (millirem/year)	Time of peak (years)	Peak dose rate (millirem/year)	Time of peak (years)
At 5 kilometers[d]	470	296,000	2,800	320,000
At 20 kilometers	170	804,000	900	712,000
At 30 kilometers	90	418,000	500	932,000
At discharge location[e]	30	872,000	120	702,000

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. 80 kilometers at Franklin Lake Playa

Table 5-11 lists peak radionuclide concentrations in water at four human exposure locations for the intermediate thermal load scenario. The peak concentrations would be from the first 10,000 years after

Table 5-11. Peak radionuclide concentrations (picocuries per liter) in water and associated annual drinking water dose at human exposure distances for 10,000 years after repository closure for the intermediate thermal load scenario.

	Mean consequence[a,b]				95th-percentile consequence[c]			
	Distance (kilometers)[d]				Distance (kilometers)			
Radionuclide	5	20	30	80	5	20	30	80
Carbon-14	1.2	1.1	4.4×10^{-1}	1.6×10^{-2}	9.6	5.9	6.7×10^{-1}	4.1×10^{-2}
Iodine-129	8.0×10^{-2}	5.5×10^{-2}	2.9×10^{-2}	1.1×10^{-3}	7.2×10^{-1}	4.3×10^{-1}	4.8×10^{-2}	2.8×10^{-3}
Neptunium-237	9.1×10^{-5}	8.0×10^{-9}	7.5×10^{-16}	2.2×10^{-23}	1.3×10^{-6}	4.2×10^{-14}	5.1×10^{-22}	2.4×10^{-24}
Protactinium-231	1.5×10^{-14}	5.0×10^{-26}	3.8×10^{-26}	3.8×10^{-26}	1.2×10^{-26}	1.6×10^{-24}	1.6×10^{-24}	7.6×10^{-27}
Plutonium-239	6.9×10^{-6}	3.2×10^{-9}	2.4×10^{-10}	7.0×10^{-13}	6.3×10^{-10}	3.0×10^{-10}	2.7×10^{-12}	2.5×10^{-11}
Plutonium-242	4.8×10^{-8}	2.2×10^{-11}	1.4×10^{-12}	4.8×10^{-15}	3.5×10^{-12}	1.8×10^{-12}	9.3×10^{-15}	1.7×10^{-13}
Selenium-79	9.4×10^{-2}	4.3×10^{-4}	2.6×10^{-6}	2.0×10^{-21}	5.0×10^{-1}	1.8×10^{-18}	1.3×10^{-18}	3.1×10^{-21}
Technetium-99	2.1×10^{1}	1.7×10^{1}	4.5	3.7×10^{-1}	4.3×10^{2}	1.8×10^{2}	1.7×10^{1}	1.1
Uranium-234	1.9×10^{-5}	4.0×10^{-11}	7.8×10^{-17}	2.9×10^{-23}	1.3×10^{-7}	6.3×10^{-16}	2.9×10^{-23}	2.1×10^{-23}
Gross alpha[e]	9.8×10^{-5}	1.1×10^{-8}	2.4×10^{-10}	7.0×10^{-13}	1.3×10^{-6}	3.1×10^{-10}	2.7×10^{-12}	2.5×10^{-11}
Annual drinking water dose (millirem)	4.1×10^{-2}	3.1×10^{-2}	1.1×10^{-2}	6.5×10^{-4}	6.2×10^{-1}	2.9×10^{-1}	2.9×10^{-2}	1.8×10^{-3}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. The concentrations for the mean and 95th-percentile consequences are the concentrations that yielded the mean and 95th-percentile doses listed in Table 5-8.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. By regulatory convention, the gross alpha does not include uranium.

repository closure. The table also lists the gross alpha-particle activity (excluding uranium). The drinking water dose is associated with drinking exactly 2 liters (approximately 0.5 gallon) of water each day. For both the mean and 95th-percentile consequences, the gross alpha activity would be much lower than the 15 picocuries per liter specified as the attainment limit for drinking water for community water systems [40 CFR Part 141 Subpart 15(a)]. The dose rates from drinking 2 liters (0.5 gallon) of water a day would also be below the 4-millirem-per-year limit for community water systems [40 CFR Part 141 Subpart 16(a)].

5.4.3 CONSEQUENCES FROM THE GROUNDWATER EXPOSURE PATHWAY FOR THE LOW THERMAL LOAD SCENARIO

Under the low thermal load scenario, the same inventory of materials would be placed in the repository as under the high thermal load scenario. This scenario would differ from the high thermal load scenario by increased spacing between the emplacement drifts and increased spacing between waste packages in the drifts. Thus, the radioactive and chemically hazardous contamination would be spread over about 10 square kilometers (2,500 acres) rather than the approximately 3 square kilometers (740 acres) used for the high thermal load scenario.

Table 5-12 lists the mean and 95th-percentile consequences of the set of 100 peak dose rates computed for the low thermal load scenario. It also lists the dose to the maximally exposed individual and the resultant probability of a latent cancer fatality. The radionuclides contributing the most to the individual dose in 10,000 years would be iodine-129, technetium-99, and carbon-14. Figure 5-6 shows how peak dose increases over the first 10,000 years at the 20-kilometer (12-mile) distance and would remain at or below 0.1 millirem per year during that time.

Table 5-12. Consequences for a maximally exposed individual from groundwater releases of radionuclides during 10,000 years after repository closure for the low thermal load scenario.

MEI[a]	Mean consequence[b]		95th-percentile consequence[c]	
	Peak dose rate (millirem/year)[d]	Probability of an LCF[e]	Peak dose rate (millirem/year)[d]	Probability of an LCF
At 5 kilometers[f]	1.3×10^{-1}	4.7×10^{-6}	1.6×10^{-1}	5.6×10^{-6}
At 20 kilometers	5.9×10^{-2}	2.1×10^{-6}	6.1×10^{-2}	2.1×10^{-6}
At 30 kilometers	4.0×10^{-2}	1.4×10^{-6}	2.3×10^{-2}	8.1×10^{-7}
At discharge location[g]	5.3×10^{-4}	1.9×10^{-8}	1.9×10^{-3}	6.6×10^{-8}

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
e. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).
f. To convert kilometers to miles, multiply by 0.62137.
g. 80 kilometers at Franklin Lake Playa.

Table 5-13 lists the population doses associated with the low thermal load scenario. The scaling factor for changing the dose rate for the maximally exposed individual into a dose rate for a member of the population was computed by diluting 57,000 cubic meters (46 acre-feet) of water infiltrating through the repository (see Section I.4.5.3) by the annual water use in the Amargosa Valley of about 17.3 million cubic meters (14,000 acre-feet). The repository infiltration rate would not increase in proportion to the decreased thermal load because, as the repository expanded, DOE would use additional areas where the infiltration rates would be different than those for the repository areas under the high thermal load scenario.

Table 5-13. Population consequences from groundwater releases of radionuclides during 10,000 years after repository closure for the low thermal load scenario.

Case	Mean consequence[a]		95th-percentile consequence[b]	
	Population dose (person-rem)	Population LCF[c]	Population dose (person-rem)	Population LCF
Peak 70-year lifetime	1.1×10^{-2}	5.3×10^{-6}	6.2×10^{-3}	3.1×10^{-6}
Integrated over 10,000 years	2.7×10^{-1}	1.3×10^{-4}	1.2×10^{-1}	6.0×10^{-5}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
c. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).

Table 5-14 lists the same type of results as those in Table 5-12, but the interval is 1 million years after repository closure. The radionuclides that would contribute the most to the peak dose rate would be neptunium-237, plutonium-242, and plutonium-239. As with the 10,000-year case, this table indicates no meaningful trend due to thermal load in comparison to the similar table for higher thermal load scenarios.

Table 5-15 lists peak radionuclide concentrations in water at four human exposure locations for the low thermal load scenario for the 10,000-year period. It also lists the gross alpha particle activity (excluding uranium). For the mean and 95th-percentile consequences, the gross alpha activity would be much lower than 15 picocuries per liter at all distances. The dose rates associated with drinking exactly 2 liters (0.5 gallon) of water each day are provided. As with the other results in this section, this table indicates no meaningful trend due to thermal load in comparison to the similar table for higher thermal load scenarios (Table 5-7).

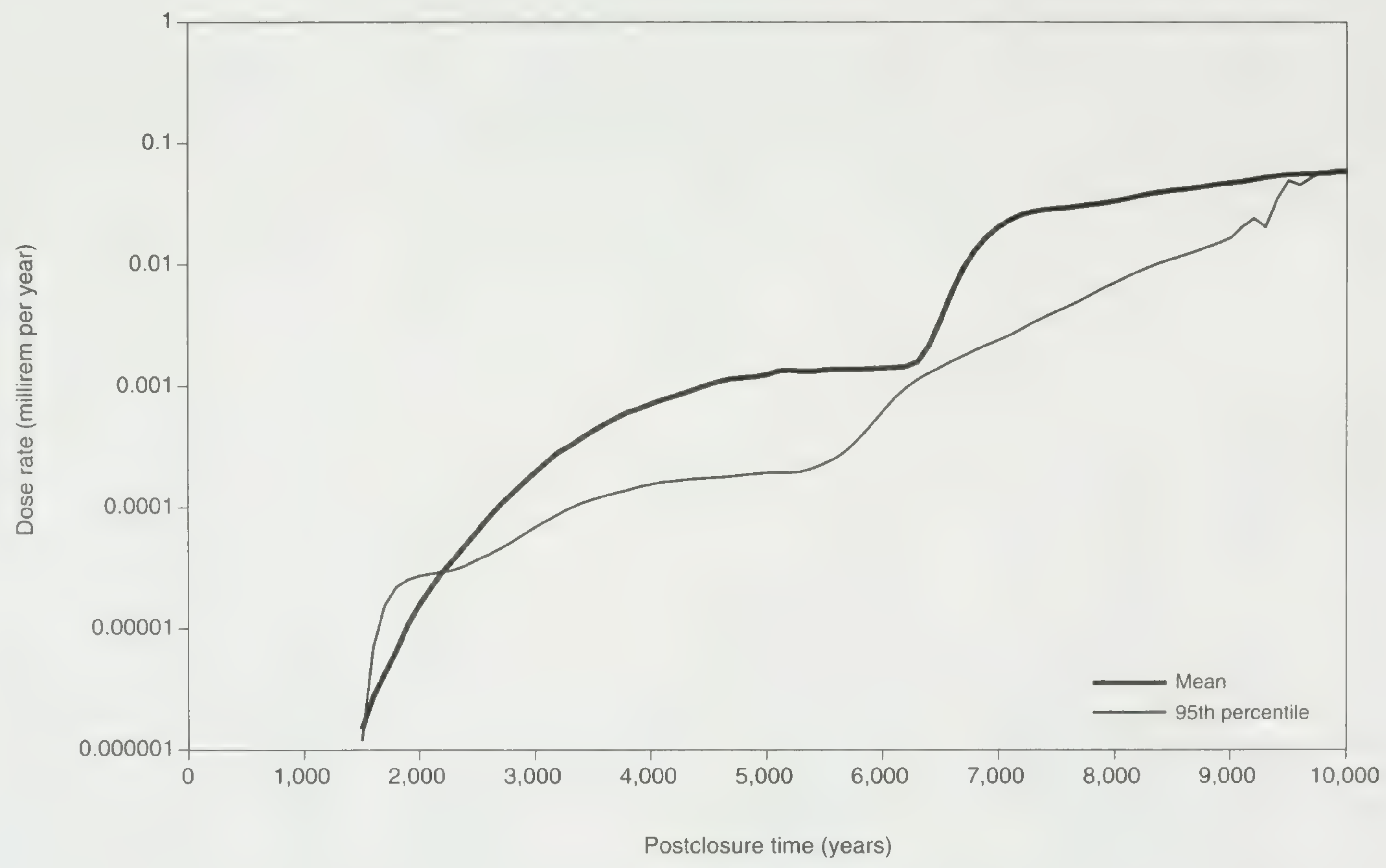


Figure 5-6. Peak dose increases over the first 10,000 years at 20 kilometers (12 miles) from the repository.

Table 5-14. Maximally exposed individual doses from groundwater releases of radionuclides during 1 million years after repository closure for the low thermal load scenario.

	Mean[b]		95th-percentile[c]	
MEI[a]	Peak dose rate (millirem/year)	Time of peak (years)	Peak dose rate (millirem/year)	Time of peak (years)
At 5 kilometers[d]	630	296,000	3,600	320,000
At 20 kilometers	160	804,000	860	334,000
At 30 kilometers	70	400,000	360	308,000
At discharge location[e]	40	824,000	160	726,000

a. MEI = maximally exposed individual.
b. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. 80 kilometers at Franklin Lake Playa.

Table 5-15. Peak radionuclide concentrations (picocuries per liter) in water and associated annual drinking water dose at human exposure distances for 10,000 years after repository closure for the low thermal load scenario.

	Mean consequence[a,b]				95th-percentile consequence[c]			
	Distance (kilometers)[d]				Distance (kilometers)			
Radionuclide	5	20	30	80	5	20	30	80
Carbon-14	1.6	7.9×10^{-1}	4.0×10^{-1}	6.7×10^{-3}	5.6	5.9	2.1×10^{-1}	3.1×10^{-2}
Iodine-129	1.0×10^{-1}	5.0×10^{-2}	2.3×10^{-2}	4.8×10^{-4}	4.0×10^{-1}	1.5×10^{-1}	1.8×10^{-25}	2.4×10^{-3}
Neptunium-237	7.3×10^{-4}	9.3×10^{-12}	2.2×10^{-16}	9.1×10^{-23}	1.4×10^{-6}	4.0×10^{-12}	7.1×10^{-25}	7.1×10^{-25}
Protactinium-231	1.4×10^{-16}	2.6×10^{-24}	7.8×10^{-26}	7.9×10^{-26}	1.6×10^{-16}	7.7×10^{-27}	2.2×10^{-27}	2.2×10^{-27}
Plutonium-239	9.4×10^{-5}	2.4×10^{-9}	1.1×10^{-9}	6.5×10^{-13}	2.5×10^{-13}	7.7×10^{-16}	4.0×10^{-14}	7.7×10^{-13}
Plutonium-242	6.9×10^{-7}	1.6×10^{-11}	5.5×10^{-12}	4.5×10^{-15}	3.2×10^{-16}	4.3×10^{-18}	2.8×10^{-16}	5.5×10^{-15}
Selenium-79	2.7×10^{-1}	4.4×10^{-6}	8.9×10^{-12}	7.8×10^{-22}	3.2	1.8×10^{-7}	1.7×10^{-21}	1.6×10^{-20}
Technetium-99	1.7×10^{1}	7.3	4.5	7.2×10^{-2}	1.9	1.4×10^{1}	6.3	3.4×10^{-1}
Uranium-234	3.1×10^{-6}	1.5×10^{-12}	4.1×10^{-16}	1.5×10^{-23}	2.0×10^{-7}	6.7×10^{-11}	6.2×10^{-24}	6.2×10^{-24}
Gross alpha[e]	8.2×10^{-4}	2.4×10^{-9}	1.1×10^{-9}	6.6×10^{-13}	1.4×10^{-6}	4.0×10^{-12}	4.0×10^{-14}	7.7×10^{-13}
Annual drinking water dose (millirem)	4.4×10^{-2}	1.9×10^{-2}	1.0×10^{-2}	1.8×10^{-4}	9.5×10^{-2}	5.3×10^{-2}	7.0×10^{-3}	9.1×10^{-4}

a. Based on four sets, one for each distance, of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. The concentrations for the mean and 95th-percentile consequences would be the concentrations that yielded the mean and 95th-percentile doses reported in Table 5-12.
c. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. By regulatory convention, the gross alpha does not include uranium.

5.4.4 SENSITIVITY STUDY ON THE FUEL CLADDING MODEL

The analysis assumed that the zirconium alloy cladding on about 0.1 percent of the fuel rods in commercial spent nuclear fuel would fail before the fuel was placed in the repository. This failure rate is two times higher than that reflected in data reported by the Electric Power Research Institute (TRW 1998k, pages 6-25 to 6-27). A modeling assumption underlying the groundwater-based consequences described in Sections 5.4.1 through 5.4.3 is that the intact cladding on the spent fuel rods would be very resistant to corrosion. Rothman (1984, all) compared the oxidation rates assessed by six different authors and estimated that corrosion amounts would vary from 4 to 53 micrometers (0.00016 to 0.0021 inch) for cladding exposed for 10,000 years at 180° C (356° F) in a wide variety of chemical conditions at lower and higher pHs than those estimated for the repository. The six corrosion models used a temperature

dependency that estimated near-zero corrosion rates for long-term repository temperatures. A recent paper confirmed the ability of zirconium alloy cladding to resist corrosion in the Yucca Mountain environment (Hillner, Franklin, and Smee 1998, all). The typical cladding for fuel rods would be 570 micrometers (0.022 inch) thick. The cladding model used for this analysis estimated that between 0.3 and 40 percent of the zirconium alloy fuel rod cladding would fail after 1 million years (DOE 1998a, Volume 3, page 4-12).

Because zirconium alloy has been used as a cladding on fuel rods for a little over 40 years, there are different opinions about its ability to provide long-term protection (over thousands of years) of fuel rod contents. There is some uncertainty about whether the radioactive and thermal environment inside the waste packages would alter the zirconium alloy enough that it would not provide much protection against waste mobilization after the waste package failed. DOE performed a sensitivity analysis to assess the importance of cladding protection on dose impacts. Additional stochastic (random) runs for 10,000 and 1 million years after repository closure were performed under the assumption that the zirconium alloy cladding would provide no resistance to water or radionuclide movement after the waste package failed. Table 5-16 compares the peak dose rate from groundwater transport of radionuclides for the two different cladding models. The analysis used data representing the high thermal load scenario to calculate individual exposures for a 20-kilometer (12-mile) distance.

Table 5-16. Comparison of consequences for a maximally exposed individual from groundwater releases of radionuclides using different fuel rod cladding models under the high thermal load scenario.

	Mean consequence[a]		95th-percentile consequence[b]	
Maximally exposed individual	Dose rate (millirem/year)	Probability of an LCF[c]	Dose rate (millirem/year)	Probability of an LCF
Peak at 20 kilometers[d] within 10,000 years after repository closure with cladding credit	0.22	7.6×10^{-6}	0.58	2.0×10^{-5}
Peak at 20 kilometers within 10,000 years after repository closure without cladding credit	5.4	1.9×10^{-4}	15	5.3×10^{-4}
Peak at 20 kilometers within 1 million years after repository closure with cladding credit	260	9.0×10^{-3}	1,400	5.0×10^{-2}
Peak at 20 kilometers within 1 million years after repository closure without cladding credit	3,000	1.1×10^{-1}	10,800	3.8×10^{-1}

a. Based on sets of 100 simulations of total system performance, each using random samples of uncertain parameters.
b. Represents a value for which 95 out of the 100 simulations yielded a smaller value.
c. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).
d. To convert kilometers to miles, multiply by 0.62137.

A comparison of the peak dose rates for the 10,000-year analysis showed that the estimated human health effects would increase if credit for the zirconium alloy cladding were eliminated. The estimated consequences would be approximately 25 times larger for both the mean and 95th-percentile consequences. A comparison of the peak dose rates for the 1-million-year analysis showed that the estimated human health effects would increase by a smaller amount if the zirconium alloy cladding were eliminated. The increase was about 12 times the mean consequence and 8 times the 95th-percentile consequence. Similar impacts would occur to drinking water concentrations.

The no-cladding analysis assumed that the zirconium alloy cladding would not provide any barrier to water movement and radionuclide mobilization after the waste package failed. However, DOE expects that the zirconium alloy would provide some impediment to radionuclide mobilization if the waste package was breached (DOE 1998a, Volume 3, page O-8). Therefore, the results for no cladding credit listed in Table 5-16 could be viewed as upper bounds on dose and health effects.

5.5 Atmospheric Radiological Consequences

After DOE closed the repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. Still, the rock is porous and does allow gas to flow, so the analysis must consider possible airborne releases. The only radionuclide in the analysis after screening (see Table 5-1) with a potential for gas transport is carbon-14 in the form of carbon dioxide. Iodine-129 can exist in a gas phase, but DOE expects it would dissolve in the groundwater rather than migrate as a gas. The solubility of iodine-129 is a great deal higher than that of carbon dioxide, and the water is already saturated in carbon dioxide because of interaction with carbonate rocks. After the carbon-14 escaped as carbon dioxide from the waste package, it would flow through the rock. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in a gas phase in the space (or gap) between the fuel and the cladding around the fuel (Oversby 1987, page 92). The atmospheric model used a gas-phase inventory of 0.234 curie of carbon-14 per waste package of commercial spent nuclear fuel at the time of emplacement. The atmospheric model estimated human health impacts for the population in the 84-kilometer (52-mile) region surrounding the repository and for the global population.

5.5.1 CARBON-14 SOURCE TERM

The calculation of regional doses used an estimate of the annual release rate of carbon-14. The analysis based the carbon-14 release rate on the estimated time line of container failures for the high thermal load scenario, using average values for the stochastic (random) parameters that were input. The expected number of spent nuclear fuel waste package failures as a function of time was used to estimate the carbon-14 release rate after repository closure. The amount of material released from each package as a function of time was reduced to account for radioactive decay. As for the waterborne releases described in Section 5.4, some credit was taken for the intact zirconium alloy cladding (on approximately 99 percent of the spent nuclear fuel by volume) delaying the release of gas-phase carbon-14. The zirconium alloy cladding on 0.1 percent of the fuel was assumed to have failed in the reactor environment (DOE 1998a, Volume 3, page 3-97), and the stainless-steel cladding on approximately 1.2 percent of the total spent fuel inventory was also assumed to have failed before it was placed in the waste package. Thus, gas-phase releases from this fuel would have occurred before it was shipped to the repository. Appendix I contains more details on the release model and reports a sensitivity study that assumed some of the stainless-steel cladding was intact when placed in the waste package. The maximum annual-release rate would occur about 19,000 years after repository closure. The estimated maximum release rate is 9.8×10^{-8} curies per year.

5.5.2 ATMOSPHERIC CONSEQUENCES TO THE LOCAL POPULATION

DOE used the GENII program (Napier et al. 1997, all) to model the atmospheric transport and human uptake of the released carbon-14 for the 84-kilometer (52-mile) population dose calculation. Doses to the regional population around Yucca Mountain from carbon-14 releases were estimated using the population distribution shown in Chapter 3, Figure 3-21, which indicates that 28,000 people would live in the region surrounding Yucca Mountain in 2000. The computation also used current (1993 to 1996) annual average meteorology (see Appendix I, Table I-5). GENII calculated a dose factor of 2.2×10^{-9} person-rem per microcurie per year of release. For a 0.098-microcurie-per-year release, this corresponds to a 7.8×10^{-15} rem-per-year average dose to individuals in the population. Thus, a maximum 84-kilometer population dose rate is 2.2×10^{-10} person-rem per year. This dose rate corresponds to 1.1×10^{-13} latent cancer fatality in the regional population of 28,000 persons during each year at the maximum carbon-14 release rate. This annual dose yields an average lifetime dose of 1.5×10^{-8} rem over a 70-year lifetime, corresponding to 7.6×10^{-12} latent cancer fatality during the 70-year period of the maximum release rate.

5.6 Consequences from Chemically Toxic Materials

A number of materials that DOE would place in the repository are hazardous to human health at sufficient concentrations in water. This section examines the consequences to individuals in the Amargosa Valley from releases of nonradioactive materials. Appendix I, Section I.3.2 describes the screening analysis DOE used to select constituents for detailed analysis.

5.6.1 HUMAN HEALTH IMPACTS FROM CHROMIUM

There would be about 14,000 metric tons (15,000 tons) of chromium in the repository under the Proposed Action (see Table 5-2). About 70 percent of the chromium would be in the Alloy-22 used for the corrosion-resistant layer of the waste packages, and the remainder would be in stainless-steel components inside the waste packages (for example, brackets, fixtures, separators, some cladding, and additional interior canisters). Chemical modeling studies of the corroding waste packages showed that the hexavalent form of chromium would dominate, primarily because the environment at the point of corrosion would have a very low pH and because there would be enough oxygen to support the complete oxidation of chromium. The hexavalent form is highly soluble and toxic to humans.

There are two measures for comparing the human health effects for chromium. When the Environmental Protection Agency established its Maximum Contaminant Level Goals, it considered safe levels of contaminants in drinking water and the ability to achieve these levels with the best available technology. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (0.0000062 pound per cubic foot) (40 CFR 141.51). The other measure for comparison is the reference dose factor for chromium, which is 0.005 milligram per kilogram (0.0004 ounce per pound) of body mass per day (EPA 1998a, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal.

One hundred simulations were run to model the release and transport of chromium for 10,000 years following repository closure. The consequences were computed at the distances used for waterborne radionuclide impacts [5, 20, 30, and 80 kilometers (3, 12, 19, and 50 miles) from the repository]. Results from a two-stage model accounting for both chromium from the inner shell of Alloy-22 and the interior stainless-steel components in some of the waste forms (spacers, grids, hardware, cladding, additional containment cans, etc.) demonstrated that the interior stainless steel mass could be neglected in estimating peak chromium concentrations in the accessible environment. Therefore, the calculation of the release rate of chromium from the repository used the inventory and corrosion rate of Alloy-22. Appendix I contains details on the chromium modeling runs. Table 5-17 lists the peak chromium concentrations computed for each model run.

Table 5-17. Peak chromium concentrations (milligrams per liter)[a] in water for 10,000 years after closure at four locations by thermal load scenario.[b]

	High thermal load		Intermediate thermal load		Low thermal load	
MEI[c]	Mean	95th-percentile	Mean	95th-percentile	Mean	95th-percentile
At 5 kilometers[d]	0.0085	0.037	0.0029	0.0096	0.0046	0.016
At 20 kilometers	0.0028	0.012	0.0023	0.010	0.0018	0.0083
At 30 kilometers	0.0018	0.0063	0.00080	0.0038	0.00067	0.0033
At 80 kilometers	0.00022	0.00061	0.000031	0.00015	0.000053	0.00034

a. To convert milligrams per liter to pounds per cubic foot, multiply by 0.0000624.
b. Based on 100 simulations of total system performance using random samples of uncertain parameters.
c. MEI = maximally exposed individual.
d. To convert kilometers to miles, multiply by 0.62137.

For the high thermal load scenario, the mean peak concentrations would range from a high of 8.5×10^{-3} milligram per liter (5.3×10^{-7} pound per cubic foot) at 5 kilometers (3 miles) down to 2.2×10^{-4} milligram per liter (1.4×10^{-8} pound per cubic foot) at 80 kilometers (50 miles). The 95th-percentile peak concentrations would range from a high at 5 kilometers of 0.037 milligram per liter (2.3×10^{-6} pound per cubic foot) down to 6.1×10^{-4} milligram per liter (3.8×10^{-8} pound per cubic foot) at 80 kilometers. Because none of the estimated concentrations exceed the Maximum Contaminant Level Goal or reference dose factor, DOE anticipates no detrimental impacts to water quality due to chromium contamination under the high thermal load scenario.

For the intermediate thermal load scenario, the mean peak concentrations would range from a high of 2.9×10^{-3} milligram per liter (1.8×10^{-7} pound per cubic foot) at 5 kilometers (3 miles) down to 3.1×10^{-5} milligram per liter (1.9×10^{-9} pound per cubic foot) at 80 kilometers (50 miles).

The 95th-percentile peak concentrations would range from a high at 5 kilometers (3 miles) of 0.01 milligram per liter (6.2×10^{-7} pound per cubic foot) down to 1.5×10^{-4} milligram per liter (9.4×10^{-9} pound per cubic foot) at 80 kilometers (50 miles). Because none of the estimated concentrations exceed the Maximum Contaminant Level Goal or reference dose factor, DOE anticipates no detrimental impacts to water quality due to chromium contamination under the intermediate thermal load scenario.

For the low thermal load scenario, the mean peak concentrations would range from a high of 4.6×10^{-3} milligram per liter (2.9×10^{-7} pound per cubic foot) at 5 kilometers (3 miles) down to 5.3×10^{-5} milligram per liter (3.3×10^{-9} pound per cubic foot) at 80 kilometers (50 miles). The 95th-percentile peak concentrations would range from a high at 5 kilometers of 0.016 milligram per liter (1.0×10^{-6} pound per cubic foot) down to 3.4×10^{-4} milligram per liter (2.1×10^{-8} pound per cubic foot) at 80 kilometers. In some instances (for example, 5 and 80 kilometers), the chromium concentrations are higher for the low thermal load than the intermediate thermal load. This is caused by the effect of the repository-area shape on the calculation of the dilution factors used for the saturated zone and the correlative differences in the percolation flux. Section I.5.2 in Appendix I discusses these factors with respect to waterborne radioactive materials (this discussion is also applicable to waterborne chemically toxic materials). Because none of the estimated concentrations exceed the Maximum Contaminant Level Goal or reference dose factor; DOE anticipates no detrimental impacts to water quality due to chromium contamination under the low thermal load scenario.

At present, the carcinogenicity of hexavalent chromium by the oral route of exposure cannot be determined because of a lack of sufficient epidemiological and toxicological data (EPA 1998a, page 48; EPA 1998b, all). Therefore, the groundwater concentrations reported in Table 5-17 cannot be expressed in terms of human health effects (latent cancer fatalities).

5.6.2 HUMAN HEALTH IMPACTS FROM MOLYBDENUM

The Alloy-22 to be used as a waste package inner-barrier would contain 13.5 percent molybdenum. During the corrosion of Alloy-22, molybdenum would mobilize almost in the same manner as chromium. Due to the corrosion conditions, molybdenum would dissolve in a highly soluble hexavalent form. Because the releases of both chromium and molybdenum would be constrained by the degradation rate of Alloy-22, the source term concentration for molybdenum would be approximately 0.64 (13.5/21.25) times the source term concentration for chromium. Detailed transport modeling of molybdenum would use the same mechanisms and parameters as those for chromium, so modeling is unnecessary. Molybdenum in the water at concentrations 0.64 times those reported above for chromium is a reasonable estimate. No regulatory standard for molybdenum has been established. Because the concentrations are very low, DOE

anticipates no detrimental impacts to water quality due to molybdenum contamination under any of the thermal load scenarios.

5.6.3 HUMAN HEALTH IMPACTS FROM URANIUM (AS A CHEMICALLY TOXIC MATERIAL)

DOE ran 100 simulations to model the release and transport of uranium for the Proposed Action inventory. The Proposed Action inventory would contain approximately 70,000 MTHM (see Table 5-2). While a small percentage of the heavy metal in the spent fuel would not be uranium, assuming that all of it is uranium is reasonable because such an assumption would have a very small effect on the result. Furthermore, the analysis would tend to overestimate health effects because it assumed that the MTHM basis of high-level radioactive waste is uranium when there is very little uranium in that material. This introduces an approximate 7-percent increase into the result (see Table 5-2 and the accompanying discussion). The simulations were based on the high thermal load scenario, and the consequences were computed for exposures at 5 kilometers (3 miles) from the repository. In addition, the analysis assumed that uranium did not undergo radioactive decay. Appendix I contains more details of the modeling runs. The maximum uranium concentration over 10,000 years was calculated for each model simulation. The mean peak concentration of uranium would be 6.7×10^{-8} milligram per liter (5.2×10^{-9} pound per cubic foot) and the 95th-percentile peak concentration would be 2.2×10^{-8} milligram per liter (1.7×10^{-9} pound per cubic foot). The Environmental Protection Agency has proposed a Maximum Contaminant Level of 0.02 milligram per liter (0.02 part per million) (56 *FR* 33050, July 18, 1991). Because the concentrations would be very low (about 1 million times less than the proposed Maximum Contaminant Level), DOE anticipates no detrimental impacts to water quality due to uranium contamination under any of the thermal load scenarios.

The reference dose for elemental uranium is 0.003 milligram per kilogram of body mass per day (Eckerman and Ryman 1993, all). Assuming a maximum individual exposure from the drinking water pathway, the analysis used a 2-liter (0.52-gallon)-per-day intake rate and a 70-kilogram (153-pound) body weight to convert the reference dose to a threshold concentration, which would be 0.105 milligram per liter (0.0000063 pound per cubic foot). There is no Maximum Contaminant Level for elemental uranium.

Based on trends in waterborne radioactive material results, the concentrations of elemental uranium at more distant locations [20, 30, and 80 kilometers (12, 19, and 50 miles)] would be even lower. This observation also applies to the intermediate and low thermal load scenarios at all distances. Because of the extremely low concentrations calculated from these simulations, further simulations were not performed to evaluate other thermal loads under the Proposed Action. The calculated concentrations were many orders of magnitude below the threshold. Therefore, DOE believes elemental uranium would not present a health risk as a chemically toxic material under the Proposed Action for any thermal load scenario.

5.7 Consequences from Disruptive Events

The postclosure performance estimates discussed above include the possible effects of changing climate but do not address events that could physically disturb the repository. In general, disruptive events have identifiable starting and ending times, in contrast to continuous processes such as corrosion. The disruptive events examined in this section are an inadvertent intrusion into the repository by a drilling crew, seismic activity, and basaltic igneous (volcanic) activity. The choice of these three events is consistent with the analyses in the Viability Assessment (DOE 1998a, Volume 3, pages 4-80 to 4-102). The results in Section 5.7 are derived from that document, with no new model runs being performed for this EIS. The Viability Assessment used a model run, called the base case, as a reference case to determine the magnitude of impacts from the disruptive events. The base case is the same as the analysis

for 85 MTHM per acre thermal load doses evaluated at a 20-kilometer (12-mile) distance in this EIS (the results are summarized in Table 5-4). The base case discussed in this section used the mean values of all the stochastic (random) parameters as inputs.

5.7.1 DRILLING INTRUSIONS

Human intrusion is generally interpreted to mean inadvertent penetration of the repository (such as by drilling operations) that would either release radionuclides at the surface or accelerate radionuclide transport to the dose-exposure location. The National Academy of Sciences has recommended that the direct impact of human intrusion not be considered in Total System Performance Assessment (National Research Council 1995, Chapter 4). The analysis reported here used the consequences of human intrusion, in terms of potential increases in long-term doses to the exposed public rather than impacts to the drilling crew, to measure the resilience of the repository to such disturbances. The Viability Assessment contains further details of the analysis and its basis (DOE 1998a, Volume 3, pages 4-99 to 4-102).

The analysis of human intrusion assumed that 10,000 years after closure, a drilling operation would penetrate the repository. The drilling event was modeled as occurring at 10,000 years after repository closure because waste packages probably would be degraded enough that a drill could penetrate them. The analysis also assumed that the intrusion would penetrate a waste package with a 21-centimeter (8.3-inch) drill bit. It assumed that the drilling proceeded through the waste package and down to the level of the water table. When the drill bit was removed, radioactive waste would fall down the drill hole to the saturated zone beneath the repository. There, flowing water would dissolve the waste and carry it to the accessible environment.

The analysis modeled a case in which 550 kilograms (1,200 pounds) of waste dropped down the hole and then dissolved at a slow rate (Figure 5-7) [considered a lower bounding situation (DOE 1998a, pages 4-99 to 4-102)]. The peak dose for this case in the first 10,000 years after the intrusion would be about 3.7 times that of the base case peak dose. Another case was modeled in which 2,700 kilograms (5,950 pounds) of waste fell down the hole and dissolved at a high rate [considered an upper bounding situation (DOE 1998a, pages 4-99 to 4-102)]. The peak dose for this case in the first 10,000 years after the intrusion (between 10,000 and 20,000 years after repository closure) would be about 145 times that of the base case peak dose about 2,000 years after the intrusion. By 10,000 years after the intrusion, there would be little difference between the doses for the base case and the doses from the intrusion cases. At 50,000 years after the intrusion, the doses from the intrusion cases would rise above that of the base case and stay elevated for approximately 100,000 years. The short-term increase in dose would be caused largely by rapid mobilization of technetium-99 and iodine-129. The long-term increase in dose would be caused largely by slower moving radionuclides such as plutonium.

In terms of the peak dose to a critical group over 100,000 years, the effects of human intrusion would be small (an increase approximately four times greater than the base case peak dose rate for about 50,000 years). Over 1 million years, the increase over the base case peak dose rate would be very small. At times close to the human intrusion event, the increased dose rates could be much larger than the corresponding base case rates.

If the drilling mud carried waste package contents to the surface, it would result in direct exposure of the drilling crew to those contents. The exposure to the drilling crew probably would result in lethal doses to those workers.

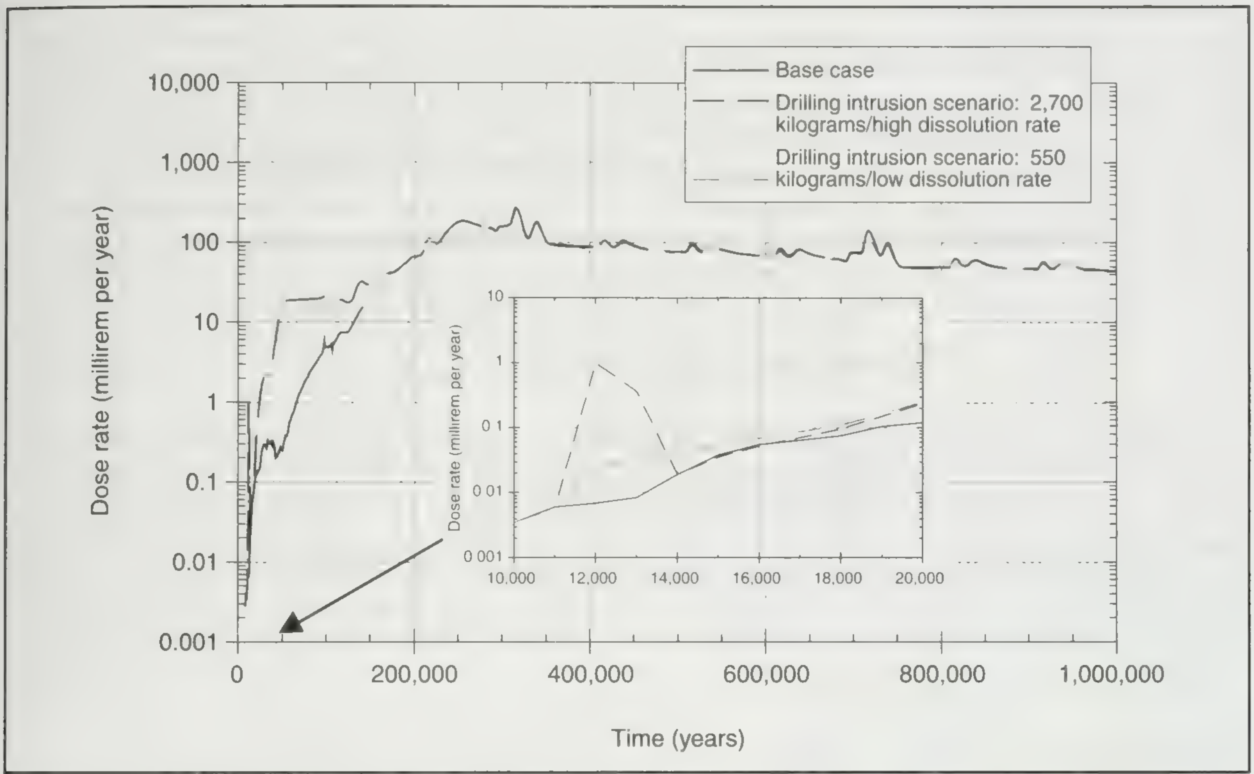


Figure 5-7. Comparison of time history of dose for the base case and under drilling intrusion scenarios 20 kilometers from the repository for the high thermal load scenario.

5.7.2 VOLCANIC DISTURBANCES

DOE has evaluated the probability of volcanic activity affecting the proposed repository (Geomatrix and TRW 1996, all). The primary criteria in defining the probability are the recurrence rate of future volcanic events and the spatial distribution of the events. The evaluation showed that it is unlikely that liquid magma or pyroclasts (hot gases that condense in air and form ash) from a volcano would intersect the repository. However, because there is a finite probability of such an occurrence, the analysis has evaluated it. The annual probability of this event occurring is 1.5×10^{-8} for the high thermal load scenario and 5.1×10^{-8} for the low thermal load.

DOE analyzed the effect on repository performance for three scenarios (DOE 1998a, Volume 3, pages 4-81 through 4-88):

- Direct release scenario: Radioactive material would be transported directly to the surface and atmosphere by a magma flow or pyroclastic flow.
- Enhanced source term scenario: Radioactive material would be entrained in magma that remained in the emplacement drift.
- Indirect igneous effects scenario: Magma would change the hydrologic flow in the saturated zone and alter the transport path of the radioactive material.

Direct Release Scenario

In this scenario the waste packages would be contacted by ascending magma or by pyroclastic flow. The Monte Carlo model determined when the volcanic event would occur, if a volcanic event would intersect an emplacement drift, if the event would intersect a container, if the waste package was breached how much material would be removed from a waste package, and if the ascending magma or pyroclasts could transport the waste. Because of its low velocity, the magma would not be removed from the waste package. Therefore, the dose to humans from this scenario was calculated based on the dispersal of radioactivity in volcanic ash. If the waste was not moved to the surface, it would collect somewhere underground and could contribute to the enhanced source term scenario. Less than 6 percent of all events would release contaminants into an ash cloud. Modeling of the direct release volcanism indicates that there would be very little impact from this scenario. The maximum dose rate from this scenario would be about 2 million times less than the maximum dose from the base case.

The calculation of radiation dose to humans from the air release scenario was based on the dispersal of contaminants in volcanic ash. The ash dispersal model (Jarzemba, LaPlante, and Poor 1997, all) uses information on eruption characteristics, wind direction and velocity, and ash and waste characteristics. Because the corrosion-resistant layers of the waste packages would maintain their structural integrity, few additional contaminant releases caused by eruptive events would be likely in the first 100,000 years after repository closure. The maximum dose from airborne ash caused by volcanism any time during the first 1 million years after repository closure would be about one million times less than the peak dose from the undisturbed groundwater transport of radionuclides.

Enhanced Source Term Scenario

The model for the enhanced source term scenario examined the interaction of the magma with waste packages in the emplacement drift and assumed that the magma would remain underground. The magma was predicted to contact between 0 and 170 packages, with an average of about 45. In this environment of high temperatures and aggressive gases, the waste package would fail. If the waste packages failed, the liquid magma could dissolve some of the uranium oxide in the spent fuel (Westrich 1982, all). When the basalt cooled [in about 10 years for a 2-meter (6.6-foot)-wide dike], groundwater would reenter the emplacement drifts. The basalt would crack as it cooled, allowing the groundwater to dissolve the uranium oxide and other radioactive materials in the contaminated basalt. The groundwater then would carry the contaminants through the geologic media to the accessible environment.

In one Monte Carlo calculation, the volcanic event would intersect waste packages at approximately 110,000 years after repository closure and would result in a peak dose four times the peak dose of the base case, with the peak occurring about 350,000 years after repository closure (DOE 1998a, Volume 3, pages 4-81 through 4-88). The other example assumed the event would occur about 740,000 years after repository closure and would result in a peak dose three times the base case peak dose. In both examples, the peak dose at the accessible environment would occur thousands of years after the event because of the time needed for groundwater to transport the radionuclides.

If an igneous event occurred in the first 100,000 years after repository closure, it would produce doses many times greater than the base case dose for the same period. The peak dose for the base case during the first 100,000 years after closure would range from 0 to 8 millirem per year. The corresponding peak dose if an igneous event occurred during the first 100,000 years after closure would range from 8 to about 64 millirem per year, which is much lower than the peak dose of about 200 millirem per year that would occur several hundred thousand years after closure. The increase in dose from an igneous event would be the result of the early rupture of a few waste packages. After doses from the waste released by interaction with the magma migrated in the groundwater to the accessible environment, the dose histories would coincide with the base case. The Viability Assessment (DOE 1998a, Volume 3, pages 4-81 to 4-88) provides detailed notes comparing results with and without volcanism.

Indirect Igneous Effects Scenario

Modeling of the indirect effects of nearby igneous events has shown that newly formed geologic structures (faults or dikes) upstream from the repository would have no effect on contaminant transport. To calibrate the flow model, it was necessary to make the hydraulic conductivity of existing structures very low (Wilson et al. 1994, Volume I, Table 11-1). Thus, making the structures even more of a barrier through igneous intrusion would cause no noticeable change in the groundwater flow patterns. When downgradient dikes are modeled as being more transmissive, there would be a small change in the groundwater flow pattern. Generally, flow would be directed more toward the east and could take longer to reach a water withdrawal well; thus, it would not be expected to increase the dose rates.

5.7.3 SEISMIC DISTURBANCES

The probability of earthquake occurrence in the Yucca Mountain vicinity is sufficiently high that DOE evaluated potential effects of seismic activity on repository performance (DOE 1998a, Volume 3, pages 4-88 to 4-92). The potential effects of seismic activity would be vibratory ground motion in the repository, causing falling rock to damage waste packages, and a nearby event causing changes in hydrologic properties. The *Probabilistic Seismic Hazard Analysis* (USGS 1998, all) estimated fault displacement and vibratory ground motion hazards in the Yucca Mountain vicinity. The results are in the form of annual frequencies that various levels of fault displacement and vibratory ground motion would exceed.

Seismic activity could cause rocks to fall from the ceilings or walls of the repository drifts. The size of falling rocks was correlated with vibratory ground motion. The distribution of the size of rocks available to fall was estimated from fracture spacing in the Exploratory Studies Facility at Yucca Mountain. Most rocks weigh less than 1,000 kilograms (2,200 pounds), with many weighing about 50 kilograms (110 pounds). There are very few rocks larger than 3,500 kilograms (7,700 pounds). Most waste package failures caused by seismic activity probably would occur when the waste package outer wall was completely corroded. After emplacement, rocks would have to be larger than any observed in the Exploratory Studies Facility to damage the waste packages. If the corrosion-allowance material and half of the corrosion-resistant material were corroded, a rock similar to the average-size rock in the Exploratory Studies Facility could damage a waste package. At times greater than 100,000 years after repository closure, damage from falling rocks would be more likely because the waste packages would be corroded. Because the waste packages would occupy about 40 percent of the space in a drift, a falling rock would have a 40-percent chance of hitting a waste package.

There is less than a 1 percent probability that a falling rock would breach a waste package during the first 10,000 years after repository closure because most waste package walls would still be thick enough to withstand such hits. Over 1 million years, falling rocks could breach about 30 percent of the waste packages in the repository. Such failures, when added to the normal failures from corrosion, would not change the overall probability of waste package failure much because they would occur mostly very late (more than 500,000 years) after emplacement. The calculations show that there would be almost no effect on repository performance from rockfall over a 1-million-year period after closure.

The Viability Assessment (DOE 1998a, Volume 3, pages 4-88 to 4-92) examined whether seismic activity in the Yucca Mountain vicinity would have the potential to affect repository performance, even if a new fault did not intersect the repository. Faulting in the saturated zone could potentially change water flow patterns and, therefore, repository performance. The saturated zone modeling assumed that most of the groundwater flow would occur in fractures, so the addition of a new fault would not be likely to alter repository performance.

5.8 Nuclear Criticality

Isolated nuclear criticality events could occur if the engineered control measures in the waste packages failed and other conditions (such as the presence of water) occurred. In addition, fissile material in the waste could form a critical configuration in the surrounding rock. Criticality has not been included in earlier total system performance analyses, but the DOE waste package design team performed an extensive investigation of this possibility (DOE 1998a, Volume 3, page 4-92). DOE found that the consequences of criticality would be relatively small in comparison to the measures for nominal repository performance.

An analysis of an in-package criticality scenario for commercial spent nuclear fuel used conditions and waste characteristics that potentially maximize the effects of the criticality (DOE 1998a, Volume 3, page 4-96). There are three possible ways that criticality could contribute to additional long-term impacts:

- Internal criticality of the package that would cause an increase of heat, the effect of which could change the properties affecting mobilization of waste
- Internal criticality that would cause an increase in the amount of radioactive material in the waste package
- External criticality resulting from a reaccumulation in the rock of fissile material that had leaked from the package

The analysis showed that the increase in heat from a highly unlikely internal criticality event would be only about 2 kilowatts per package, which is inconsequential in comparison to the overall repository heat load. The increase in radioactivity would be only 24 percent of the original radioactivity in the waste package for a 10,000-year criticality duration. Because of the small increases in radioactivity and heat output, there is no chance that a criticality would cause mechanical disruption of the waste package and engineered barrier system (DOE 1998a, Volume 3, page 4-98).

Criticalities outside the waste packages primarily would require some mechanism to accumulate the fissile material in a localized area. The estimated concentrations would be less than 0.01 percent by volume for plutonium, which is much too low to make criticality possible (DOE 1998a, Volume 3, page 4-98).

Based on these results, DOE concluded that an explosive nuclear criticality is not credible (could not occur). If a nuclear criticality event occurred (highly unlikely) it would not have a significant effect on long-term impacts from the repository.

5.9 Consequences to Biological Resources and Soils

DOE considered if the proposed repository would affect biological resources in the Yucca Mountain vicinity after closure through heating of the ground surface and through radiation exposure as the result of waste migration through groundwater to discharge points. After closure, heat from the radioactive decay of the waste would cause temperatures in the rock near the disposal containers to rise above the boiling point of water [100°C (212°F)] (DOE 1998a, Volume 3, page 3-36). The period the subsurface temperature would remain above the boiling point would vary from a few hundred years to a few thousand years, depending on the thermal load scenario. Conduction and the flow of heated air and water through the rock (advection) would carry the heat from the disposal containers through the rock to the surface and to the aquifer.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils probably would increase slightly. Predicted increases in surface soil temperatures range from approximately 10°C (18°F) at the bedrock-soil interface (Bodvarsson, Bandurraga, and Wu 1997, page 510) to 6°C (10.8°F) for dry soil at a depth of 2 meters (6.6 feet) (Table 5-18). To address soil heterogeneity (differences in depth and water content), a recent study (TRW 1999r, all) modeled soil temperature increases at various depths under wet (saturated) and dry (no water at all) soil conditions for the high thermal load. They predicted that temperatures of near-surface soils would be unlikely to rise more than a few degrees (Table 5-18) but would increase with depth from the surface. Surface soil temperatures would start to increase after approximately 200 years and would peak after about 1,000 years. Later, the temperature would gradually decline and would approximate prerepository conditions after 10,000 years (TRW 1999r, Figure 4-13). The maximum change in temperature would occur directly above the repository, affecting approximately 3 square kilometers (740 acres) under the high thermal load scenario. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository (TRW 1999r, page 49). Although not modeled, the increase in surface soil temperature would be lower under the intermediate and low thermal load scenarios, and the area that could be affected would be larger [as much as 10 square kilometers (2,500 acres) above the repository for the low thermal load scenario].

Table 5-18. Predicted temperature changes of near-surface soils under the high thermal load scenario.[a]

Soil depth (meters)[b]	Predicted temperature increase[a]	
	Dry soil	Wet soil
0.5	1.5°C (2.7°F)	0.2°C (0.36°F)
1.0	3.0°C (5.4°F)	0.4°C (0.72°F)
2.0	6.0°C (10.8°F)	0.8°C (1.4°F)

a. Source: TRW (1999r, page 45).
b. To convert meters to inches, multiply by 39.37.

There is considerable uncertainty in the estimates of soil temperature increases due to uncertainties in the thermal properties of the soil at Yucca Mountain, particularly thermal conductivity (the amount of heat that can be conducted through a unit of soil per unit time) (TRW 1999r, page 50).

The predicted temperature increase for dry soil provides a conservative estimate of the temperature increase that could occur because even partially saturated soil has a much greater thermal conductivity than dry soil. Soil moisture content recorded at a depth of 15 centimeters (6 inches) was as low as 3 percent on some study sites during some months, but the soil was never completely dry (TRW 1999s, page 14).

A depth of 1 meter (3.3 feet) is within the root zone for many desert shrubs. A temperature increase of 3°C (5.4°F) could affect root growth and other soil parameters such as the growth of microbes or nutrient availability. Studies at Yucca Mountain (TRW 1999s, pages 11 to 46) show that some plant species experienced a spatial range in soil temperatures of 4°C (7.2°F) at a depth of 0.45 meter (18 inches), which is comparable to the 0.5-meter (20-inch) depth used by TRW (1999r, all). Impacts to biological resources probably would consist of an increase of heat-tolerant species over the repository and a decrease of less tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A gradual (over 1,000 years) temperature increase of the magnitude predicted (TRW 1999r, all) probably would have less effect on the plant community than a more rapid change, such as that predicted for global warming.

The predicted increase in temperature would extend as far as 500 meters (1,600 feet) beyond the edge of the repository, with the greatest increase in temperature occurring in soils directly above the repository. A shift in the plant species composition, if any, would be limited to the area within 500 meters of the repository footprint [that is, as much as 8 square kilometers (2,000 acres)], with the greatest change within the central 3 square kilometers (740 acres) for the high thermal load scenario. Although a larger area could be affected under the intermediate and low thermal loads, the magnitude of the increase in soil

temperature would be smaller and the associated effects on plant species composition would not be as pronounced as under the high thermal load.

A shift in the plant community probably would lead to localized changes in the animal community that depends on it for food and shelter. Specific plant and animal species and community changes cannot be predicted with certainty because changes in climate or seasonal episodic events (droughts, high rainfall) can substantially change species responses to single factors. However, the variation in surface soil temperatures at Yucca Mountain that are caused by elevation, slope, aspect, and other natural attributes suggest that soil temperature increases of the magnitude predicted (TRW 1999r, pages 44 to 48) are probably within the adaptive range of some plant species now at Yucca Mountain (TRW 1999s, pages 11 to 46).

Some reptiles, including the desert tortoise, exhibit temperature-dependent sex determination (Spotila et al. 1994, pages 103 to 116). Nest temperatures have a direct effect on sex determination, with lower temperatures resulting in predominately male hatchlings and higher temperatures resulting in predominately females. Although existing experimental data do not adequately represent the large fluctuations in nest temperatures in natural settings, an increase in soil temperature due to thermal load could influence the sex ratio and other aspects of the life history of the desert tortoise population residing over the repository footprint. However, depth to the top eggs of 23 nests at Yucca Mountain during 1994 averaged 11 centimeters (4.3 inches). Predicted temperature increases of clutches at that depth based on modeling results (TRW 1999r, pages 44 to 48) would be less than 0.5°C (0.9°F). Given the ranges of critical temperatures reported by Spotila et al. (1994, all), an increase of this magnitude would be unlikely to cause adverse effects.

Changes in plant nutrient uptake, growth, and species composition, as a result of increases in soil temperature over long periods of time, could influence vegetation community dynamics and possibly alter desert tortoise habitat structure in areas immediately above the repository. However, little is known about the effects that minor alterations in habitat would have on desert tortoise population dynamics.

As discussed in Sections 5.4 and 5.6, in the distant future water at certain discharge points would be likely to carry concentrations of radionuclides and chemically toxic substances. DOE did not quantify impacts to biological resources from irrigation water discharged 5, 20, and 30 kilometers (3, 12, and 19 miles) from the repository, or from the evaporation of water at Franklin Lake Playa (where there is no surface water at present). The estimated doses to humans exposed to this water would be very small. In a similar manner, assumed doses to plants and animals would be small and the impacts from those doses would be unlikely to affect the population of any species because the doses would be much lower than the 100-millirad-per-day limit, at which there is no convincing evidence that chronic radiation exposure will harm plant or animal populations (IAEA 1992, page 54).

The desert tortoise is the only threatened or endangered species in the analyzed repository land withdrawal area (TRW 1999k, page 3-14). Desert tortoises are rare or absent on or around playas (Rautenstrauch and O'Farrell 1998, pages 407 to 411; Bury and Germano 1994, pages 64 and 65); therefore, DOE anticipates no impacts to this species from contaminated water resources at Franklin Lake Playa in the future.

Impacts to surface soils would be possible. Changes in the plant community as a result of the presence of the repository could lead to an increase in the amount of rainfall runoff and, therefore, an increase in the erosion of surface soils, thereby increasing the sediment load in surface water in the immediate Yucca Mountain vicinity.

5.10 Summary

Potential impacts to human health in the far future from a repository at Yucca Mountain would be dominated by impacts from radioactive materials in the waterborne pathway under all three thermal load scenarios of the Proposed Action. Although future disruptive events (human intrusion, volcanic activity, and seismic activity) would change radiation exposure rates, the effect of these on the reported impacts for the undisturbed case would be small under all thermal load scenarios. Large impacts from chemically toxic materials would be unlikely.

Tables 5-4, 5-8, and 5-12 list estimated radiation dose rates for a maximally exposed individual from the groundwater release pathway during the first 10,000 years after repository closure for the three thermal load scenarios. Table 5-19 summarizes the health effects based on the average peak-dose rates to the affected population (see Section 5.3) for these three scenarios. The fact that all of the numbers in Table 5-19 are much smaller than 1.0 means that it is most likely that no person would die due to groundwater contamination by radiological material in the 10,000-year period after repository closure. The number of cancer fatalities that would normally occur each year in the population in the Amargosa Valley (assuming a population of about 1,150 persons) would be about 2. This number is based on approximately 163 cancer fatalities per year per 100,000 population for males in the United States (NIH 1999, all). This comparison clearly indicates that the human health impacts associated with the Proposed Action would be very small for the population in general.

Table 5-19. Summary of health effects for the three thermal load scenarios for the Proposed Action.[a]

Thermal load	Peak 70-year lifetime LCFs[b]	10,000-year integrated LCFs
High	7.5×10^{-6}	1.8×10^{-4}
Intermediate	3.3×10^{-6}	6.7×10^{-5}
Low	5.3×10^{-6}	1.3×10^{-4}

a. Values based on the mean peak-dose rates from 100 simulations of total system performance using random samples of uncertain parameters.
b. LCFs = latent cancer fatalities.

It is appropriate to conclude that environmental justice impacts of long-term repository performance would not be disproportionately high and adverse because minority and low-income populations and Native Americans in the Amargosa Valley would experience a very small impact from radiological dose and there would be no other impacts relevant to environmental justice issues.

As discussed, overall human health impacts to Amargosa Valley residents would be small. The reference person studied to calculate human health impacts was defined as a person who lived year-round in the Valley, consumed locally produced foods, and ingested water from potentially contaminated sources. Estimated doses to plants and animals would also be small. The definition of the reference person and the dose rate to plants and animals address several issues of concern to environmental justice populations, such as relative immobility and dependence on local sources for food and water.

Figure 5-8 shows the mean peak dose rates from Tables 5-4, 5-8, and 5-12. The mean values were based on 100 simulations of total system performance, with each simulation using random samples of uncertainty parameters. Tables 5-6, 5-10, and 5-14 contain the corresponding radiation dose rates in the first 1 million years after repository closure for the three scenarios. Figure 5-9 shows the mean peak dose rates in the first 1 million years after repository closure. The doses shown in these figures do not include the effects of disruptive events.

The analysis indicates (as shown in Figures 5-8 and 5-9 and through a comparison of Tables 5-4, 5-8, and 5-12) that there would be no clear effect of thermal load on the doses, even though the impacts for the high thermal load scenario appear to be slightly larger than the impacts for the other scenarios. One

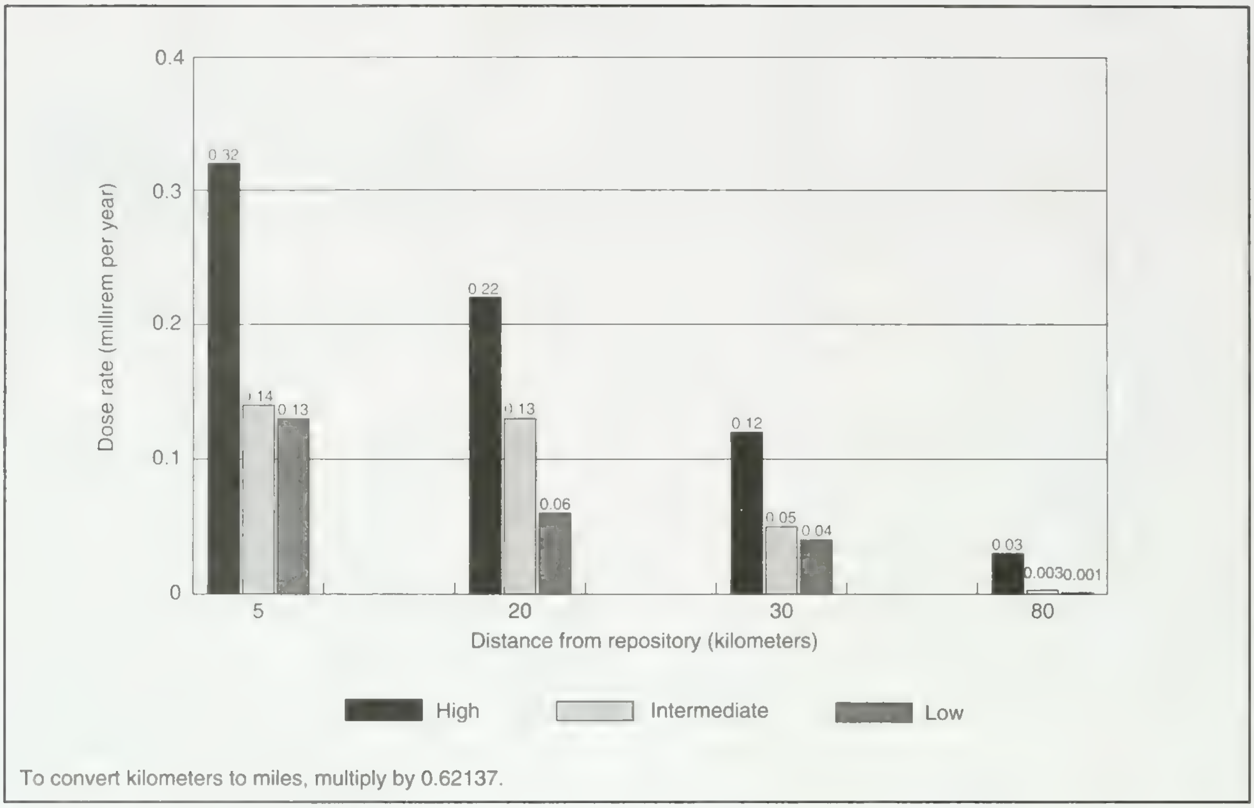


Figure 5-8. Comparison of the mean peak dose rates from contaminated groundwater in the first 10,000 years after repository closure for the three thermal load scenarios.

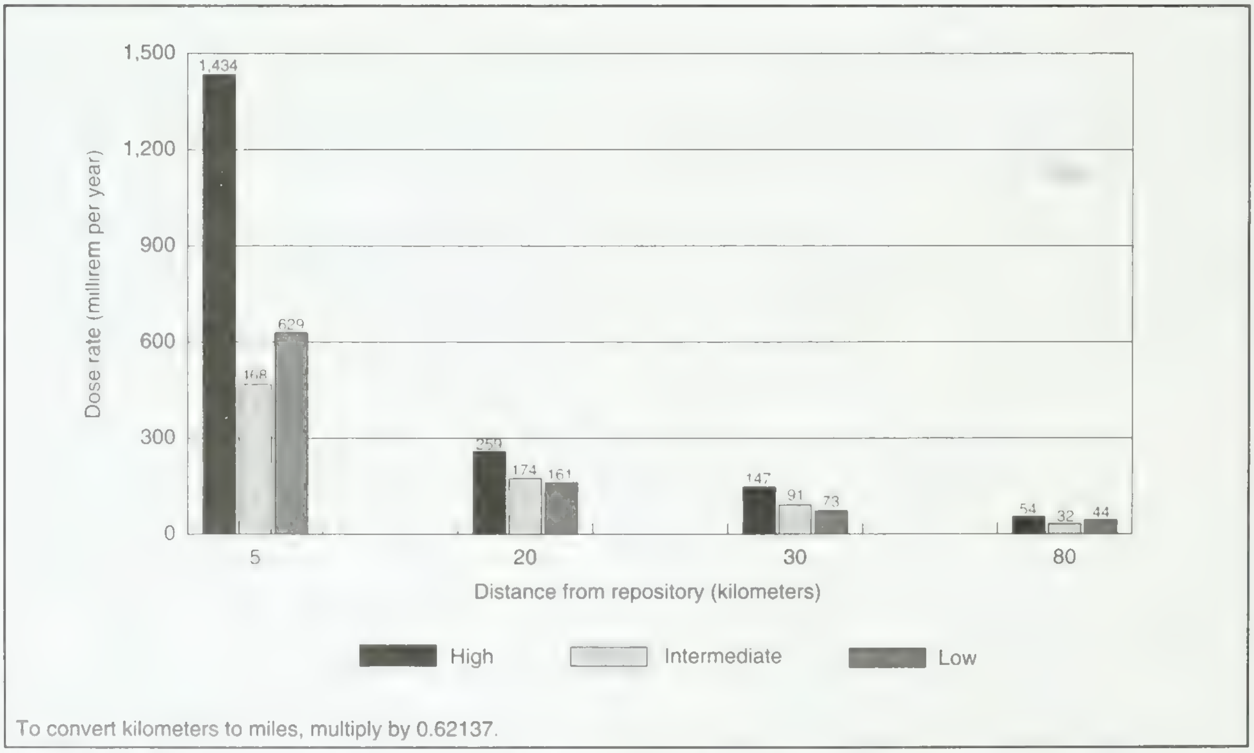


Figure 5-9. Comparison of the mean peak dose rates in the first 1 million years after repository closure for the three thermal load scenarios.

reason for the lack of difference in dose rates among thermal loads is that more than 99 percent of the waste packages would last beyond the time at which the repository temperature would be elevated much above ambient rock temperatures (DOE 1998a, Volume 3, pages 3-36 to 3-88). Thus, most radionuclides would not be released until long after the thermal effects had subsided and, therefore, thermal load would not have a large effect on the doses. The differences among thermal loads would be due to the placement of waste in different areas of the mountain, with different amounts of water infiltrating through the different areas. More details on the effect of spatially varying infiltration rates are provided in Appendix I.

The analysis also indicated that the dose to the maximally exposed individual would depend strongly on distance from the repository. The dose rates would be much higher at a 5-kilometer (3-mile) distance than at longer distances.

6

Environmental Impacts of Transportation

6. ENVIRONMENTAL IMPACTS OF TRANSPORTATION

This chapter describes the potential environmental consequences of transporting spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 U.S. Department of Energy (DOE) sites to the Yucca Mountain site under the Proposed Action. This chapter also separately describes the impacts of transportation activities in the State of Nevada.

This environmental impact statement (EIS) analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the Nuclear Waste Policy Act, as amended.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

The analysis evaluated potential impacts from two basic national transportation activities—the loading of spent nuclear fuel and high-level radioactive waste in heavily shielded shipping casks certified by the U.S. Nuclear Regulatory Commission at commercial and DOE facilities, and the transportation of these materials to Yucca Mountain using legal-weight truck or rail shipments. The Nevada transportation activities include the transportation of spent nuclear fuel and high-level radioactive waste shipments from the State borders to Yucca Mountain. Nevada transportation also includes the transportation of materials, equipment, and personnel to and from Yucca Mountain for the construction, operation and monitoring, and eventual closure of the proposed repository. The analysis also evaluated the potential impacts of the possible construction of an intermodal transfer station and related highway upgrades that might be needed for heavy-haul trucks, and the possible construction of a branch rail line to Yucca Mountain. Section 6.1 provides a summary of both national and Nevada transportation activities. Chapter 2, Section 2.1.2, also contains detailed descriptions of national transportation and Nevada transportation activities.

Section 6.2 assesses and compares the potential impacts of national transportation from the 77 sites to Yucca Mountain. Because the mode of transportation used to ship from each site would depend on several factors that DOE does not control (for example, future capabilities of shipping sites, rail service to shipping sites, and labor agreements), DOE recognizes that it cannot predict the specific transportation mode (truck or rail) of each shipment to the repository. Therefore, this section evaluates the potential

impacts of two national transportation modes (legal-weight truck and rail), which are represented in this section by two analytical scenarios—*mostly legal-weight truck* and *mostly rail*—to address the range of impacts that could occur in Nevada for the transportation modes that DOE could ultimately use. In addition, as part of the mostly rail scenario, this section assesses short hauls of commercial spent nuclear fuel in heavy-haul trucks or barges that could occur from some commercial sites to railheads.

Section 6.3 assesses potential impacts from transportation activities in Nevada. This section uses three analytical scenarios—*mostly legal-weight truck* (corresponding to that portion of the national transportation scenario that would occur in Nevada), *mostly heavy-haul truck*, and *mostly rail*—to address the range of impacts that could occur in Nevada for the transportation modes that DOE could ultimately employ. In addition, Section 6.3 evaluates the potential consequences in Nevada of using legal-weight trucks on existing routes, one of five potential highway routes for heavy-haul trucks, or one of five potential branch rail lines. The potential highway routes for heavy-haul trucks and potential branch rail corridors are called *implementing alternatives*. The EIS includes information, such as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada, that might not lead to near-term decisions. It is uncertain at this time when DOE would make these transportation-related decisions. If and when it is appropriate to make such decisions, DOE believes that the EIS provides the information necessary to make these decisions. However, measures to implement those decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, State of Nevada and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

National transportation and Nevada transportation modes must be integrated to operate effectively, as shown in Figure 6-1. Therefore, this analysis used only certain combinations of the national and Nevada transportation modes. Figure 6-2 shows the relationship of the rail and truck modes to the national and Nevada transportation analysis scenarios and the Nevada transportation implementing alternatives.

Appendix J contains details on transportation analysis methods and results. Chapter 4 evaluates potential environmental impacts from the offsite manufacturing of shipping casks for commercial and DOE (including naval) spent nuclear fuel and DOE high-level radioactive waste; the receipt and unloading of shipping casks; the preparation at the repository of empty casks for reshipment; and the construction and operation of a cask maintenance facility at the proposed Yucca Mountain Repository. Chapter 8 discusses cumulative impacts of transportation for the Proposed Action and anticipated future transportation activities that could affect members of the public and workers.

6.1 Summary of Impacts of Transportation

6.1.1 OVERVIEW OF NATIONAL TRANSPORTATION IMPACTS

This section provides an overview of the potential impacts of using the Nation's highways and railroads to transport spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites to the repository at Yucca Mountain. Detailed discussions of national transportation impacts are in Section 6.2 and analytical methods are in Appendix J. All potential impacts are related to the health and safety of populations and hypothetical maximally exposed individual members of the general public and workers. This summary includes estimated impacts from loading operations, incident-free transportation, and accidents for the mostly legal-weight truck and mostly rail national transportation scenarios. (National transportation includes transportation in Nevada to Yucca Mountain.)

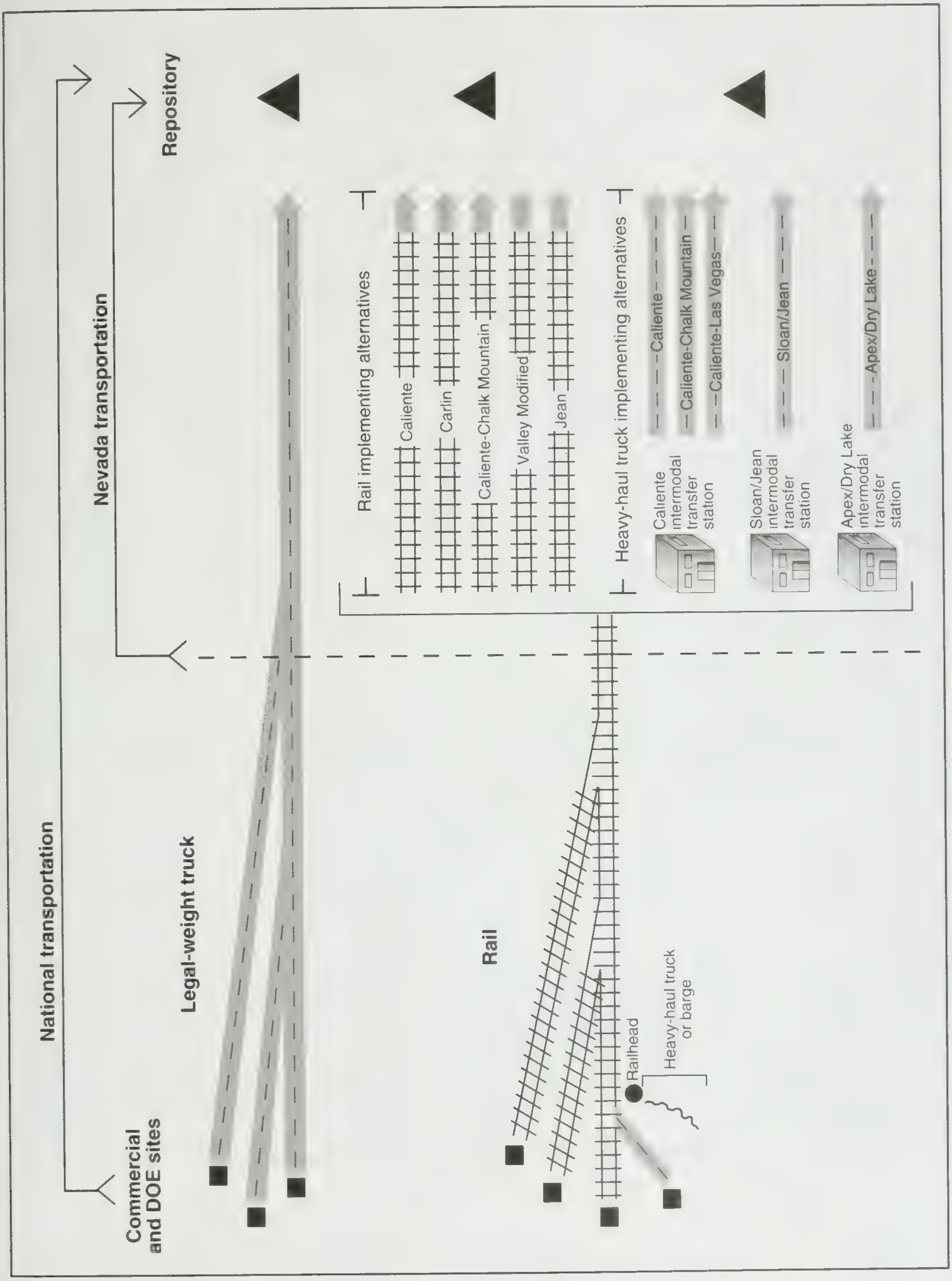


Figure 6-1. Relationship of Nevada and national transportation.

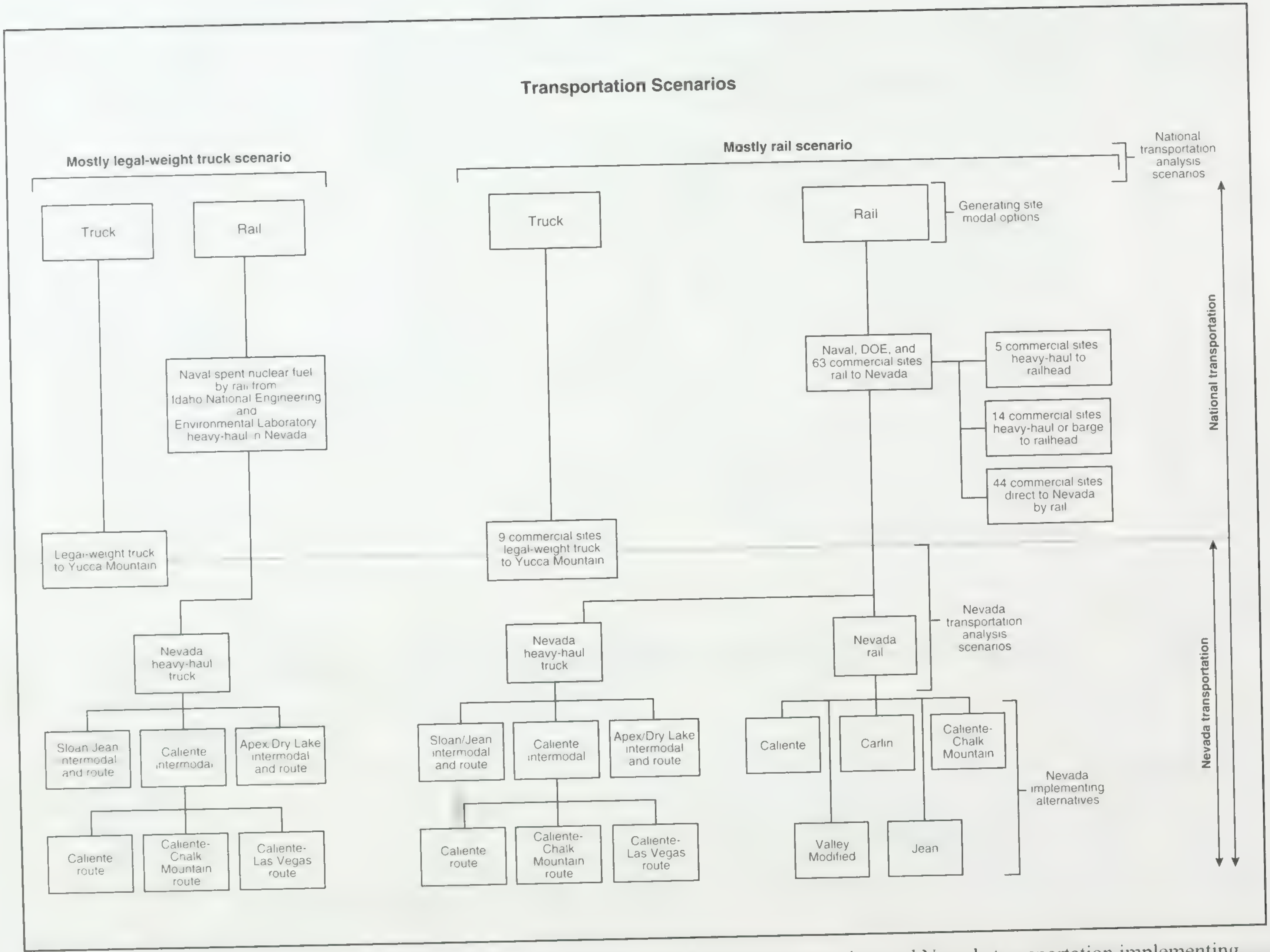


Figure 6-2. Relationship between transportation modes, national and Nevada analytical scenarios, and Nevada transportation implementing alternatives.

IMPLEMENTING ALTERNATIVES AND SCENARIOS

Implementing alternatives and scenarios are used to describe the range of reasonably foreseeable transportation actions with environmental impacts that could result from the Proposed Action.

Implementing alternatives represent feasible selections that DOE could make based in part on this EIS (for example, selecting a branch rail line corridor or an intermodal transfer station location and an associated route for heavy-haul trucks). Analytical scenarios, on the other hand, are feasible combinations of actions that DOE would have limited ability to direct (for example selecting the use of rail or truck casks for shipments from a specific nuclear powerplant). The scenarios are selected such that the analysis results bound the range of impacts that could result from the Proposed Action.

The transportation modes that make up the analytical scenarios and implementing alternatives include the following:

Legal-weight truck transportation: Legal-weight trucks have gross vehicle weights, including cargo, that do not exceed 80,000 pounds, which is the loaded weight limit for commercial vehicles operated on Interstate and U.S. highways without special state-issued permits. In addition, these vehicles would have dimensions that are within the constraints of Federal and state regulation limits.

Permitted overweight, overdimension truck transportation: Semi- and tandem tractor-trailer trucks with gross vehicle weights over 80,000 pounds must obtain permits from state highway authorities to use public highways. States often permit vehicles that have gross weights above 80,000 pounds as *overweight, overdimension* vehicles with operating restrictions to protect public safety. Nine-axle tractor-trailer trucks (steering axle and three drive axles on the tractor and three axles on the trailer) with weights greater than 80,000 pounds that meet Federal bridge formulas and dimensional limits can carry payloads of 70,000 pounds.

Rail transportation: Rail transportation includes railroad transportation of spent nuclear fuel and high-level radioactive waste in large rail transportation casks (rail casks). The casks would be placed on railroad cars at commercial and DOE sites or at nearby intermodal transfer facilities for shipment on trains operated by commercial railroad companies over existing tracks. Because of the weight of the casks, only one cask would be transported on a railcar.

Heavy-haul truck transportation: Heavy-haul truck transportation includes the movement of large rail casks—both loaded and empty—on large heavy-haul trucks traveling on existing highways. For the transportation of spent fuel and high-level radioactive waste rail casks, these vehicles would weigh as much as 500,000 pounds; they would be more than 100 feet long and 10 to 12 feet wide, and would stand as high as 15 feet above the road surface. Heavy-haul trucks would require special permits issued by a state transportation agency. The permits would normally restrict the times of operation (typically daylight, non-rush-hour), operating speeds, and highways used [see TRW (1999d, Request #031)].

Barge transportation: Barge transportation would be the transportation of loaded and empty rail casks between a commercial facility and a nearby railhead using navigable waterways. Barge terminals would have intermodal transfer capabilities sufficient to transfer casks from barges to railcars.

Estimated national transportation impacts are based on 24 years of transportation activities during the Proposed Action and average annual shipments of about 2,100 (2,100 truck, 13 rail) for the mostly legal-weight truck scenario and 560 (450 rail, 110 truck) for the mostly rail scenario. From all causes, about 23 fatalities could occur in the nationwide general population from incident-free transportation activities

of the mostly legal-weight truck scenario and about 6 fatalities from the mostly rail scenario during the 24-year transportation period (impacts of a maximum reasonably foreseeable accident are not included).

Impacts of Loading Operations

All spent nuclear fuel and high-level radioactive waste would be loaded onto trucks or railcars at the 77 sites for transport to the Yucca Mountain site. Some health and safety impacts would be associated with these loading operations. There would be small (0.04 latent cancer fatality) impacts to members of the public from loading operations. Over the 24 years of the Proposed Action, an estimated 6 and 2 latent cancer fatalities, respectively, could occur in involved worker populations from radiation exposure for the mostly legal-weight truck and mostly rail scenarios. The probability of a latent cancer fatality to the maximally exposed involved worker would be about 0.005 for both scenarios. No worker fatalities from industrial accidents would be expected. No or very small impacts to workers or members of the public would be expected from postulated loading accidents. About 0.5 traffic fatality could occur in the worker population from commuting under the mostly legal-weight truck scenario, while about 0.2 traffic fatality could occur under the mostly rail scenario. Loading operations and potential impacts are discussed further in Section 6.2.2.

Impacts of Incident-Free Transportation

Incident-free transportation is the expected norm for transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. Impacts of incident-free transportation would include those from external radiation emitted from transportation casks and vehicle exhaust emissions along the transportation routes.

Over the 24 years of the Proposed Action, an estimated 18 latent cancer fatalities could occur in the general population along transportation routes from radiation exposure under the mostly legal-weight truck scenario and an estimated 2 latent cancer fatalities could occur under the mostly rail scenario. Under the mostly legal-weight truck and mostly rail scenarios, the probability of a latent cancer fatality to the maximally exposed member of the public would be no more than 0.0012 and 0.00016, respectively. Under these same scenarios, about 0.6 and 0.3 vehicle emission-related fatality, respectively, could occur in the general population along transportation routes.

For involved workers, an estimated 5 latent cancer fatalities could occur in the involved worker population from radiation exposure for the mostly legal-weight truck scenario, and an estimated 1 latent cancer fatality could occur for the mostly rail scenario. The probability of a latent cancer fatality to the maximally exposed involved worker would be no more than 0.02 for either the mostly legal-weight truck or mostly rail scenarios. DOE expects impacts to noninvolved workers to be low, smaller than those to involved workers.

The differences in incident-free impacts between the mostly legal-weight truck and mostly rail scenarios are principally because of (1) the difference in the number of shipments for the two scenarios, and (2) differences in analysis assumptions about the numbers of in-transit stops, the number of potentially exposed persons, and their proximity to shipping casks that could result in external radiation exposure.

No environmental justice impacts were identified for incident-free transportation. Incident-free national transportation and the potential impacts to workers and the public are discussed further in Section 6.2.3.

Impacts of Transportation Accidents

The analysis evaluated transportation accident impacts to human health and safety, collectively including the health and safety of the public and transportation workers. Thus, impacts to populations from transportation accidents would include impacts to affected workers. Because of the large differences between the populations of transportation workers and the general public, radiological accident risks and

TRANSPORTATION RADIOLOGICAL ACCIDENT RISK

Transportation radiological accident risk is determined by calculating the number of latent cancer fatalities that would be caused per rem of exposure to radioactive materials from transportation accidents and multiplying this value by the probability of the accidents.

An estimated 0.0005 cancer would be caused by exposure to a dose of 1 rem. An individual exposed to a dose of 0.3 rem per year, which is approximately equal to background radiation, for a lifetime of 72 years would have a lifetime exposure of about 22 rem. This dose would result in a risk of a latent cancer fatality of 0.01. This is a probability of 1 in 100 of death over a lifetime from exposure to radiation approximately equal to natural background radiation and medical sources.

If each person in a population of 1,000 was exposed to a dose of 22 rem, the population dose would be 22,000 person-rem. Using 0.0005 latent cancer fatality per rem of dose, an analysis would estimate 11 latent cancer fatalities from this population dose.

consequences for workers would be a very small fraction of the risks and consequences evaluated for the public.

Accident impacts include the consequences where shipping casks could be breached with subsequent release of radioactive material to nearby individuals and populations. In addition, there could be impacts to individuals from "normal" traffic accidents, in which there would be no release of radioactive material from shipping casks and only those directly involved in the accident would be affected. The analysis examined radiological consequences under the maximum reasonably foreseeable accident scenario, and overall accident risk. The maximum reasonably foreseeable accident scenario is the one with the greatest potential consequences. It must also have an occurrence likelihood of 1 in 10 million per year or greater to be considered "reasonably foreseeable." Accident risk considers the potential consequences of all accident scenarios and their occurrence likelihood, from accident scenarios that are likely to occur but would have no release of radioactive material to those accident scenarios that are extremely unlikely to occur but could have large consequences (for example, the maximum reasonably foreseeable accident scenario).

The overall radiological accident risk, as described in Appendix J, Section J.1.4.2.1, from all accident scenarios over the 24 years of transportation activities during the Proposed Action would be about 0.07 latent cancer fatality for the mostly legal-weight truck scenario and about 0.02 latent cancer fatality for the mostly rail scenario. These estimated latent cancer fatalities would occur in the hypothetically exposed population residing within 80 kilometers (50 miles) of the accident site.

The maximum reasonably foreseeable accident scenario for the mostly legal-weight truck scenario would result in about 5 latent cancer fatalities in the exposed population. It is postulated to involve a release of radioactive material from a truck cask in an urbanized area under stable (still air) weather conditions. The probability of this accident scenario would be about 0.00000019 per year (a rate of about 2 in 10 million years). The maximum reasonably foreseeable accident scenario for the mostly rail scenario would result in about 31 latent cancer fatalities in the exposed population. It is postulated to involve a release of radioactive material from a rail cask in an urbanized area under stable (still air) weather conditions. The probability of this accident scenario would be about 0.00000014 per year (a rate of about 1.4 in 10 million years). The probability of a latent cancer fatality occurring in the hypothetical maximally exposed individual would be about 0.002 for the mostly legal-weight truck scenario and about 0.013 for the mostly rail scenario.

Nationwide, during the 24 years of the Proposed Action transportation activities, about 4 fatalities could result from traffic accidents under the mostly legal-weight truck scenario. For the same time period, about 4 fatalities could also result from traffic accidents under the mostly rail scenario. These fatalities would all be related to physical injuries associated with traffic accidents, not radiological impacts.

No environmental justice impacts were identified for transportation accident scenarios. Transportation accident scenarios and potential impacts are discussed further in Section 6.2.4.

6.1.2 OVERVIEW OF NEVADA TRANSPORTATION IMPACTS

This section provides an overview of the environmental impacts associated with transportation of spent nuclear fuel and high-level radioactive waste in the State of Nevada. Although this section provides a more detailed, regional subset of some of the information gathered and analyses conducted for national transportation (see Section 6.1.1), it also includes information analyzed specifically for Nevada. This includes impacts from construction and operation of branch rail lines, heavy-haul truck routes and intermodal transfer stations, commuter transportation for construction and operations activities, and transportation of other materials in support of Yucca Mountain operations. Detailed discussions of potential impacts in Nevada are in Section 6.3 and Appendix J. The following areas were evaluated for potential impacts in Nevada from Yucca Mountain transportation activities:

- Transporting spent nuclear fuel and high-level radioactive waste by legal-weight truck in Nevada
- Constructing a branch rail line in Nevada and using it to transport spent nuclear fuel and high-level radioactive waste by rail to the repository
- Upgrading highways in Nevada for use by heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the repository
- Constructing and operating an intermodal transfer station in Nevada
- Transporting materials, consumables, supplies, equipment, waste, and people to support construction, operation and monitoring, and closure of the repository

Overviews are presented for the 12 environmental resource areas analyzed in this chapter and for the transportation of other materials and supplies, which is presented in further detail in Appendix J. The summaries provide information for assessing the relative impacts in these resource areas from the mostly legal-weight truck transportation scenario, the five implementing alternatives for rail transportation, and the five implementing alternatives for heavy-haul truck transportation.

6.1.2.1 Land Use

Land-use impacts would be greatest for the mostly rail scenario, with disturbed land areas ranging from about 5 square kilometers (1,200 acres) for the Valley Modified route to 19 square kilometers (5,000 acres) for the Carlin route (see Figure 6-3). The Carlin route would also affect the most private land [7 square kilometers (1,730 acres)]. Disturbed land area would be very similar for all of the heavy-haul implementing alternatives, ranging from 0.2 to 0.28 square kilometers (50 to 70 acres). No more than 0.2 square kilometers of private land would be affected for any route. There would be no land-use impacts from legal-weight trucks using existing highways. Land-use impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

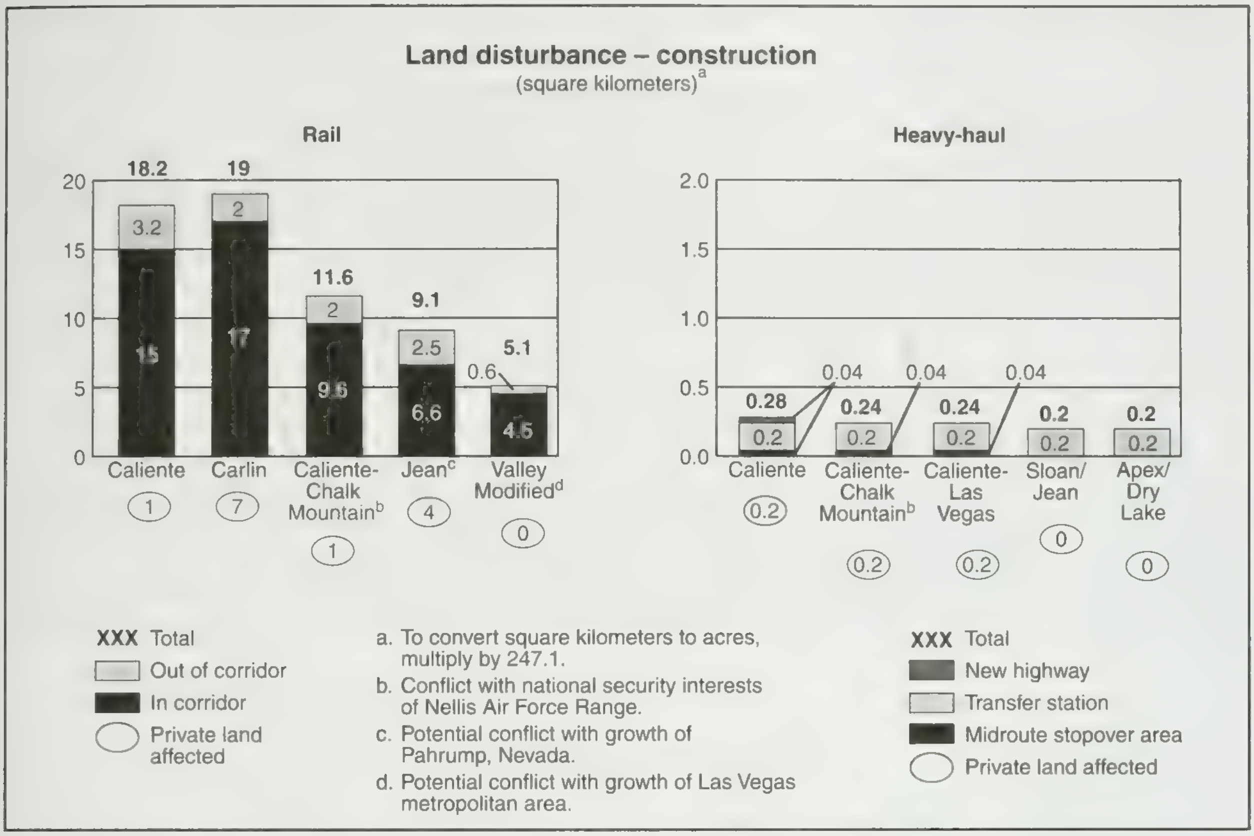


Figure 6-3. Land disturbed for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

The U.S. Air Force has identified national security issues regarding a Chalk Mountain rail corridor or Caliente-Chalk Mountain route for heavy-haul trucks, citing interference with Nellis Air Force Range testing and training activities (Henderson 1997, all). In response to Air Force concerns, DOE regards these routes as "non-preferred alternatives." The Jean and Valley Modified rail corridors could have conflicts with the future community growth of Pahrump and Las Vegas, respectively. Potential rail and legal-weight and heavy-haul truck routes could pass through or near the Moapa and Las Vegas Paiute Indian Reservations.

6.1.2.2 Air Quality

The main air pollutants would be fugitive dust and equipment emissions (mainly carbon monoxide and nitrogen dioxide) from construction or upgrade activities associated with the rail and heavy-haul truck implementing alternatives, and vehicle emissions associated with legal-weight truck, heavy-haul truck, and rail transportation. None of these emissions are expected to exceed applicable annual or short-term air quality limits. Dust (such as PM_{10} and $PM_{2.5}$) from construction would be suppressed by the use of best management practices such as water spraying. Pollutants from vehicle traffic would be small in all cases, although the largest repository-related source of vehicle emissions would be the vehicles used by employees commuting to and from the Yucca Mountain site. This traffic would originate in and return to the Las Vegas area and be a minor contributor to traffic emissions in the Las Vegas Valley. Air quality impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.3 Hydrology

Surface-water resources are most prevalent among the Caliente and Carlin rail corridors and could be affected by construction activities. The potential Caliente intermodal transfer station is about 0.19 kilometer (0.12 mile) from a perennial stream, and the Caliente, Caliente-Chalk Mountain, and Caliente-Las Vegas routes for heavy-haul trucks would pass within 1 kilometer (0.6 mile) of water resources. Surface-water impacts during construction would be avoided by implementing good management practices to prevent and mitigate spills of pollutants and would avoid, minimize, or otherwise mitigate possible changes to stream flows. Therefore, DOE does not anticipate impacts to surface waters from the construction of a rail or heavy-haul truck implementing alternative. In addition, surface-water impacts would be unlikely from legal-weight truck, rail, or heavy-haul truck operations or the operation of an intermodal transfer station.

Potential for groundwater impacts would be limited. There would be the potential for temporary withdrawals of water from groundwater sources during the construction of a branch rail line or upgrades to highways and construction of an intermodal transfer station. Estimated water use would be greater for construction of branch rail lines than for upgrades for heavy-haul truck routes (see Figure 6-4). Such withdrawals would require temporary permits from the State of Nevada. If groundwater could not be withdrawn for construction, water would be transported from permitted sources to the construction sites by truck.

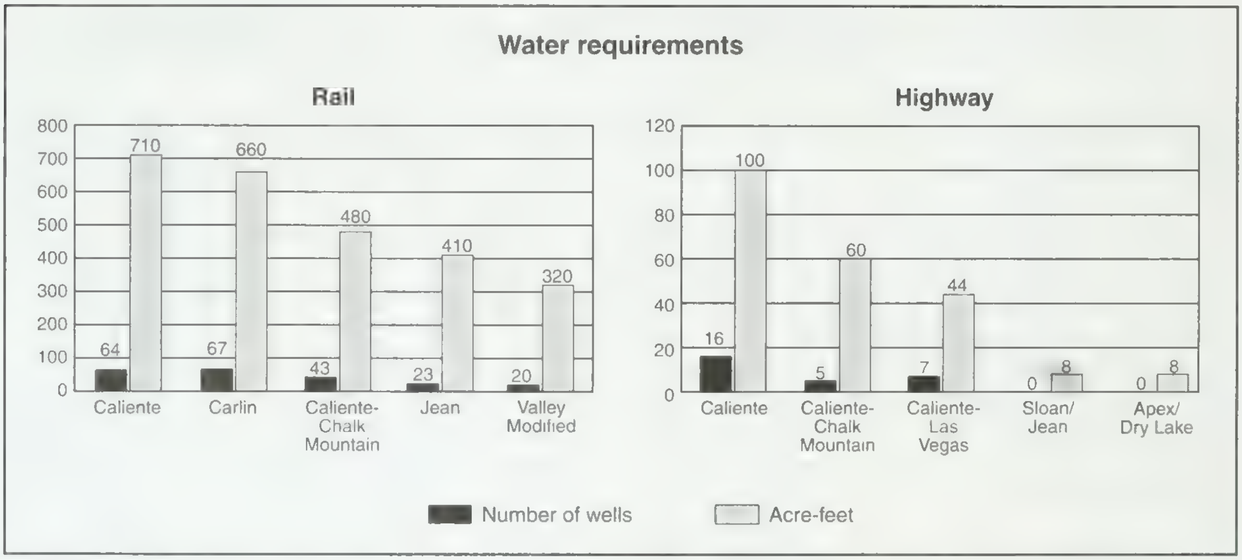


Figure 6-4. Water and number of wells required for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

Legal-weight truck shipments, operations of a branch rail line, or operations of heavy-haul trucks, including the operation of an intermodal transfer station, would not affect groundwater resources. Hydrology impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.4 Biological Resources and Soils

Loss of habitat from construction of a branch rail line would be the greatest potential impact to biological resources, potentially affecting the desert tortoise, a threatened species. Loss of desert tortoise habitat would be approximately 2.4 square kilometers (590 acres) for the Caliente-Chalk Mountain route, 3 square kilometers (740 acres) for the Caliente and Carlin routes, 5 square kilometers (1,200 acres) for

the Valley Modified route, and more than 11 square kilometers (2,700 acres) for the Jean route. All of these potential routes have low abundance of desert tortoise except for some limited areas of the Jean route where abundance is higher. The potential for impacts from upgrading Nevada highways for heavy-haul truck use would be small because modifications to roads would occur in previously disturbed rights-of-way. An intermodal transfer station constructed in association with a heavy-haul truck implementing alternative would potentially disturb only about 0.2 square kilometer (50 acres) of potential desert tortoise habitat. Other special status species could be affected based on the route chosen. Impacts from operations, with the exception of infrequent wildlife kills by vehicles, would be unlikely. As with heavy-haul trucks, legal-weight truck shipments that used existing highways would cause only very small impacts to biological resources.

For highway upgrades, DOE or the State of Nevada would reduce concerns about soil contamination or erosion as a result of implementing alternatives for transportation by incorporating appropriate considerations during construction. These considerations would include the proper control of hazardous materials and use of dust suppression and other control techniques to reduce erosion. As a result, the implementing alternatives for transportation in Nevada would be unlikely to have impacts on soil. Impacts to biological resources and soils are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.5 Cultural Resources

Based on available information, the construction and operation of a branch rail line in any of the candidate corridors could present the potential for direct or indirect impacts (such as crushing or disturbing of sites; soil erosion exposing or covering sites) to archaeological resources, including those related to Native American culture. None of the five potential rail corridors passes through reservation lands. Additional archaeological surveys and ethnographic studies would be needed for any of the five rail corridors to determine impacts and mitigation needs. The determination of the potential for impacts to archaeological resources and Native American cultural values from the upgrading and use of Nevada highways for heavy-haul truck shipments would also require more study. The Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes for heavy-haul trucks follow a portion of U.S. Highway 95 that passes through approximately 1.6 kilometer (1 mile) of the Las Vegas Paiute Indian Reservation. The Caliente-Las Vegas route segment on U.S. Highway 93 passes within about 5 kilometers (3 miles) of the Moapa Indian Reservation. An Apex/Dry Lake intermodal transfer station would be within 3 kilometers (2 miles) of the Moapa Indian Reservation. Legal-weight trucks arriving from the northeast on I-15 and rail transportation arriving from the northeast on the existing Union Pacific railroad mainline would pass through the Moapa Indian Reservation. The American Indian Writers Subgroup has commented that ethnographic field studies will be needed to determine potential impacts to Native American cultural values (AIWS 1998, page 4-6).

6.1.2.6 Occupational and Public Health and Safety

Impacts to occupational and public health and safety include industrial safety impacts to workers from construction and operations, radiological impacts to workers and the general public from external radiation exposure and exposure to vehicle emissions during normal operations and incident-free transportation, radiological impacts from transportation accident scenarios, radiological impacts from hypothetical severe accident scenarios that would breach shipping casks, and impacts from traffic accidents.

Potential industrial safety impacts to workers from construction and operations are shown in Table 6-1. Postulated fatalities from industrial accidents would be higher for rail than for heavy-haul trucks, but

Table 6-1. Industrial safety impacts to workers from construction and operation of Nevada transportation implementing alternatives.[a]

Impact	Branch rail line[b]				
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Total recordable cases	250	240	220	170	130
Lost workday cases	130	120	110	90	70
Fatalities (industrial accidents)	1.3	1.2	1.0	0.9	0.5
	Heavy-haul truck[b]				
	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Sloan/Jean	Apex/Dry Lake
Total recordable cases	340	330	300	180	180
Lost workday cases	190	180	160	100	100
Fatalities (industrial accidents)	0.7	0.6	0.6	0.4	0.4

a. Impacts are totals for 24 years of operations. There are no impacts for the legal-weight truck scenario.
b. Includes impacts to workers at an intermodal transfer station.

more recordable cases and lost workday cases were postulated to occur for heavy-haul trucks. The industrial safety-related fatalities were postulated to occur during construction of four of the five branch rail lines, while none were predicted for upgrades to routes for heavy-haul trucks and construction of an intermodal transfer station. No industrial safety-related fatalities would be expected to occur during operations.

Potential radiological impacts and vehicle emission-related impacts from normal operations and incident-free transportation in Nevada for each of the rail and heavy-haul truck implementing alternatives and for the mostly legal-weight truck scenario are presented in Table 6-2. Radiological impacts to members of the public from external radiation exposure and risks from exposure to vehicle emissions during incident-free transportation would be lowest for rail, intermediate for heavy-haul trucks, and highest for legal-weight truck transportation, where 1.4 latent cancer fatalities were estimated to occur over 24 years. Impacts from vehicle emissions would be low in all cases (0.028 or fewer fatalities).

The overall radiological accident risk from all accidents over the 24 years of transportation activities in Nevada would be no higher than about 0.002 latent cancer fatality in the potentially exposed population within 80 kilometers (50 miles). Accident risk would be highest for the heavy-haul implementing alternatives and lower for the mostly legal-weight truck scenario and rail implementing alternatives. The Jean rail and Sloan/Jean heavy-haul truck implementing alternatives would have higher accident risks than other implementing alternatives. The estimated accident risks are presented in Table 6-2. More operations jobs would be created to support heavy-haul truck transportation than for rail transportation. Socioeconomic impacts from operations activities would also be small except for Lincoln County, where impacts would be moderate. However, these impacts would not be greater than historic short-term socioeconomic changes that have occurred in the county in the past.

The Nuclear Regulatory Commission published a draft Addendum 1 (NRC 1999, all) to NUREG-1437, Volume 1, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996, all) to provide a technical basis to amend Commission regulations with the objective of improving the efficiency of renewing nuclear plant operating licenses by documenting well-understood environmental impacts to avoid repetitive reviews. The addendum addresses two aspects of spent nuclear fuel transportation that the original analysis did not address—the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, and the impacts of transporting higher-burnup fuel. The results of the EIS analysis appear to be consistent with the Nuclear Regulatory Commission conclusion in the addendum, which is that "radiological and accident

Table 6-2. Worker and public health and safety impacts from Nevada transportation implementing alternatives.[a]

Impact	Legal-weight truck	Branch rail line[b]: Caliente	Branch rail line[b]: Carlin	Branch rail line[b]: Caliente-Chalk Mountain	Branch rail line[b]: Jean	Branch rail line[b]: Valley Modified
Workers						
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.63	0.17	0.19	0.16	0.16	0.15
Public						
Maximally exposed individual probability of LCF	0.00012	0.00016	0.00016	0.00016	0.00016	0.00016
General population LCFs	1.4	0.20	0.21	0.19	0.21	0.19
Vehicle emissions-related health effects (fatalities)	0.05	0.0019	0.025	0.0017	0.014	0.0018
Accident risk						
Population LCFs	0.00006	0.000047	0.000051	0.000045	0.000076	0.000045
Maximum reasonably foreseeable accident scenario						
Population LCFs	4.7	31	31	31	31	31
Maximally exposed individual probability of LCF	0.002	0.013	0.013	0.013	0.013	0.013
Traffic accident fatalities	0.46	2.0	2.0	1.6	1.3	1.0

Impact	Heavy-haul truck[b]: Caliente	Heavy-haul truck[b]: Caliente-Chalk Mountain	Heavy-haul truck[b]: Caliente-Las Vegas	Heavy-haul truck[b]: Sloan/Jean	Heavy-haul truck[b]: Apex/Dry Lake
Workers					
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.31	0.29	0.30	0.29	0.28
Public					
Maximally exposed individual probability of LCF	0.00016	0.00016	0.00016	0.00016	0.00016
General population LCFs	1.0	0.62	0.77	0.51	0.47
Vehicle emissions-related health effects (fatalities)	0.0053	0.0033	0.0041	0.015	0.0030
Accident risk					
Population LCFs	0.0001	0.0001	0.0004	0.002	0.0003
Maximum reasonably foreseeable accident scenario					
Population LCFs	31	31	31	31	31
Maximally exposed individual probability of LCF	0.013	0.013	0.013	0.013	0.013
Traffic accident fatalities	6.3	3.3	4.0	2.3	2.3

a. Impacts are totals for 24 years of operations.
b. Includes impacts to workers at an intermodal transfer station.
c. LCF = latent cancer fatality.

risks of SNF [spent nuclear fuel] transport in the vicinity of Las Vegas are within regulatory limits and small."

6.1.2.7 Socioeconomics

Socioeconomic impacts of transportation would take place from construction and operation of branch rail lines and heavy-haul routes, including intermodal transfer stations. Figure 6-5 shows regional workforce changes for construction and operations activities. The largest number of jobs would be created by construction of branch rail lines. Because of the large population and workforce in the socioeconomic region of influence (principally Clark County), impacts from construction activities would be small for the rail and heavy-haul truck implementing alternatives except for Lincoln County (the two rail corridors and three heavy-haul truck routes originating in Caliente). Impacts in Lincoln County would be moderate; however, these impacts would not be greater than historic short-term socioeconomic changes in the county. In general, regional workforce changes from construction would be small and transient; changes in per capita real disposable income would be smaller. Changes to the baseline regional populations would be unlikely to have consequences.

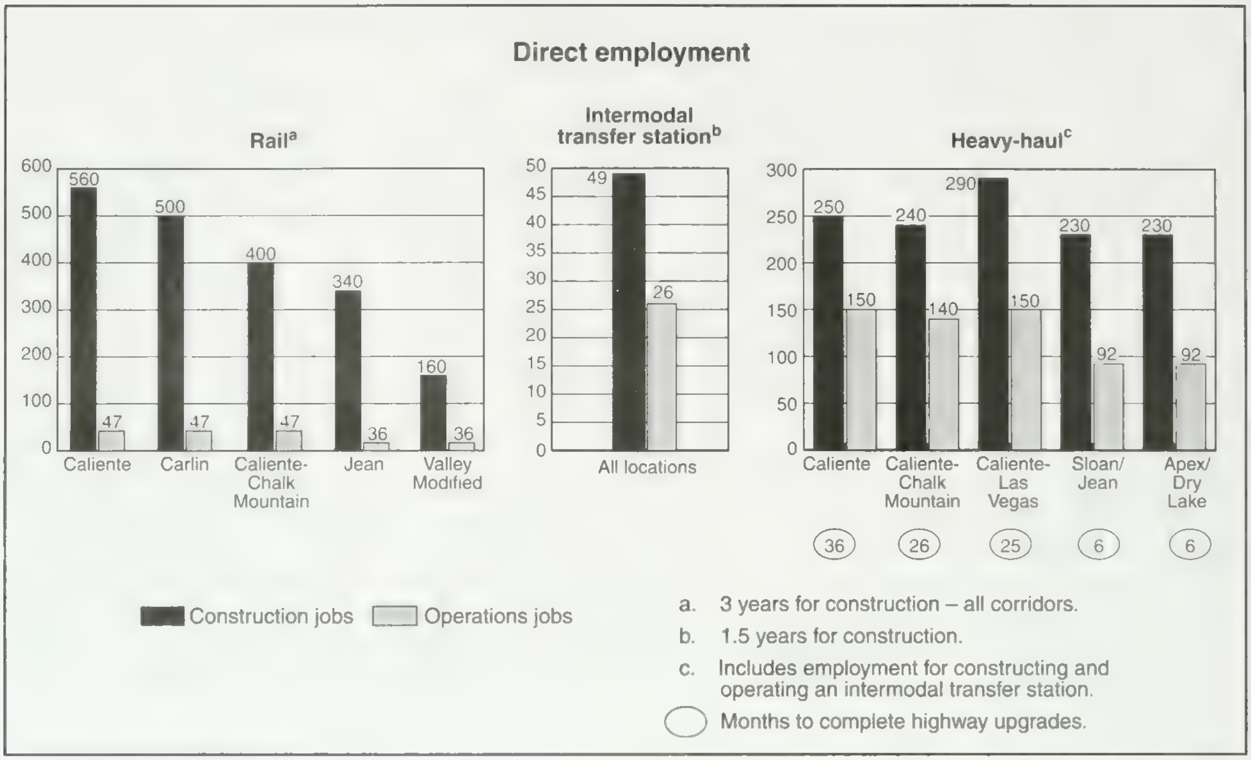


Figure 6-5. Impacts to employment from Nevada transportation alternatives.

More operations jobs would be created to support heavy-haul truck transportation than for rail transportation. Socioeconomic impacts from operations activities would also be small except for Lincoln County, where impacts would be moderate. However, these impacts would not be greater than historic short-term socioeconomic changes that have occurred in the county in the past.

6.1.2.8 Noise

Noise from the construction of a branch rail line or upgrades to highways for heavy-haul trucks would be transient and not excessive. In addition, noise from trains, which would occur during as many as five weekly round trips, would not be excessively disruptive. Heavy-haul truck operations would use existing highways that already had traffic, including semi-trailer trucks. There could be a need to identify the location of potential residents to refine the present assessment. The American Indian Writers Subgroup identified noise from transportation as a concern because of its effects on ceremonies and the solitude necessary for healing and praying.

6.1.2.9 Aesthetics

Studies have identified a potential visual resource impact for the northeastern portion of the Jean rail corridor that passes through the Spring Mountains. The character of Class II lands (defined in Chapter 3, Section 3.1.10) in that part of the corridor would change, possibly in conflict with visual resource management goals. No other rail corridors would have large or lasting aesthetic impacts. The upgrades of existing highways would present short-term aesthetic impacts during construction but these would be temporary and transient, resulting largely from widening the highways. Routes originating in Caliente could cause impacts on the Class II lands of Kershaw Ryan State Park, the entrance of which is on the east side of the Meadow Valley Wash across from a potential location for an intermodal transfer station. However, the character of this area of the Meadow Valley Wash has been modified by the Union Pacific

rail line, the City of Caliente water treatment facility, and agricultural uses of lands in the vicinity. All heavy-haul truck routes and all branch rail lines except Carlin would pass through Class III lands. Aesthetic conditions would not be affected by legal-weight trucks on existing, well-traveled highways.

6.1.2.10 Utilities, Energy, and Materials

Impacts to utility, energy, and material resources from the construction and operation of any of the rail or heavy-haul truck implementing alternatives would be small compared to usage in Nevada. For example, Nevada fossil-fuel consumption during 1996 was about 3.8 billion liters (1 billion gallons) [BTS 1999a, Table MF-21]. By comparison the largest fossil-fuel use for any of the implementing alternatives would be about 50 million liters (13 million gallons), less than 2 percent of the Nevada annual use. Similarly, concrete use for the largest implementing alternative would be about 120,000 metric tons (51,000 cubic meters), also less than 2 percent of the Nevada annual use of 7.4 million metric tons (3.2 million cubic meters) (Sherwood 1998, all). Figures 6-6 and 6-7 compare the use of resources for construction of the rail and heavy-haul truck implementing alternatives, respectively.

6.1.2.11 Wastes

Wastes from the construction of an intermodal transfer station and upgrades to highways or from the construction of a branch rail line in Nevada would be recovered for recycling, placed in permitted industrial landfills, or reused. In addition, hazardous wastes, if any, would be sent to a permitted hazardous waste facility. The operation of an intermodal transfer station and heavy-haul trucks or of a branch rail line would produce small quantities of waste. The quantities from legal-weight truck operations in Nevada would also be small. Thus, impacts from the wastes generated during Nevada transportation to support the Proposed Action would be small.

6.1.2.12 Environmental Justice

This section uses the results of analyses from other disciplines to determine if disproportionately high and adverse impacts on minority or low-income populations would be likely to occur from transportation activities. DOE does not expect disproportionately high and adverse impacts to minority or low-income populations from the Proposed Action. The environmental justice analysis involved a two-stage assessment of the potential for disproportionately high and adverse impacts on minority and low-income populations:

- First, a review of the activities included in the Proposed Action to determine if they would be likely to result in high and adverse human health impacts or in environmental impacts that could affect human populations

- Second, if the first-stage review identified high and adverse impacts to human populations in general, an analysis of these impacts as described above to determine if they could be disproportionately high and adverse for minority or low-income populations

If the first-stage review does not identify impacts to human populations, a second-stage analysis for potential environmental justice impacts is not required because there would not be high and adverse impacts to any part of the human population, including minority and low-income populations.

No potentially disproportionately high and adverse impacts to minority or low-income populations were identified in areas of land use; air quality; hydrology; biological resources and soils; socioeconomics; aesthetics; and occupational and public health and safety for construction or operations under the mostly legal-weight truck scenario in Nevada or any of the 10 rail and heavy-haul truck transportation

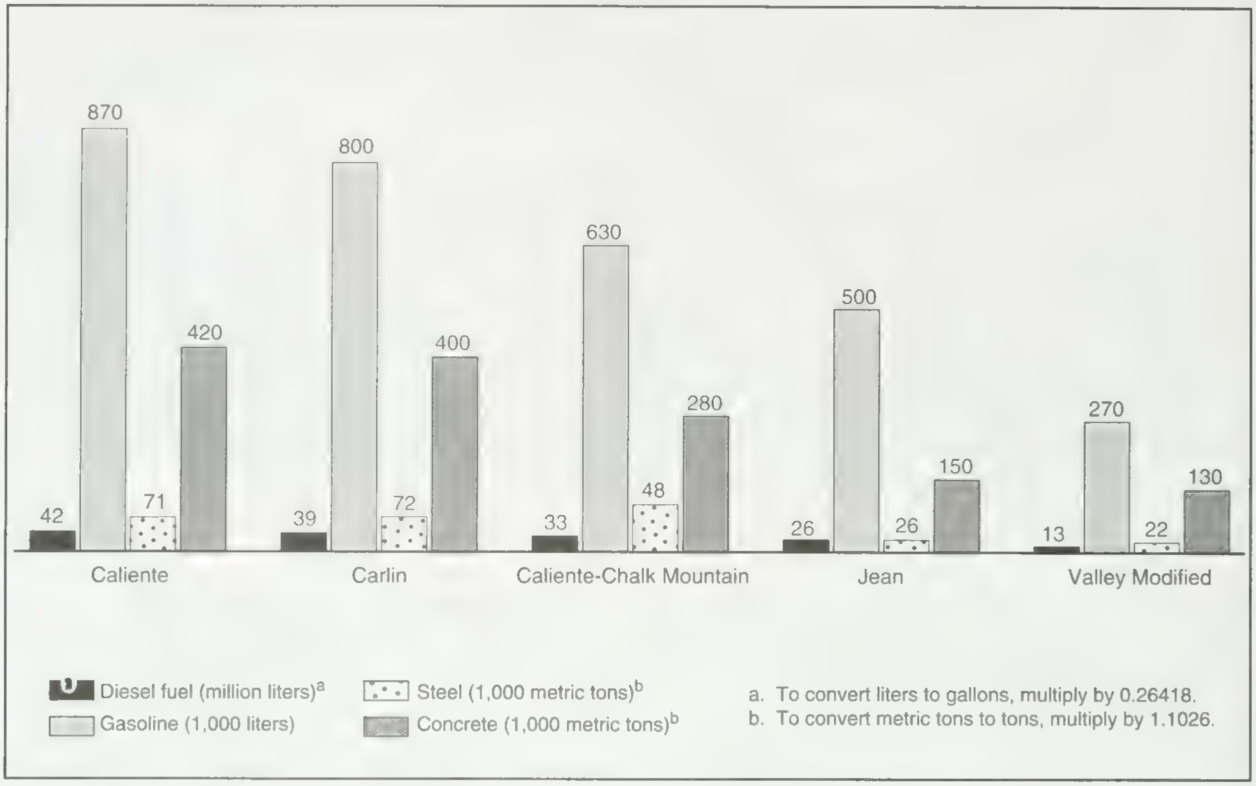


Figure 6-6. Utility, energy, and material use for construction of a branch rail line in Nevada.

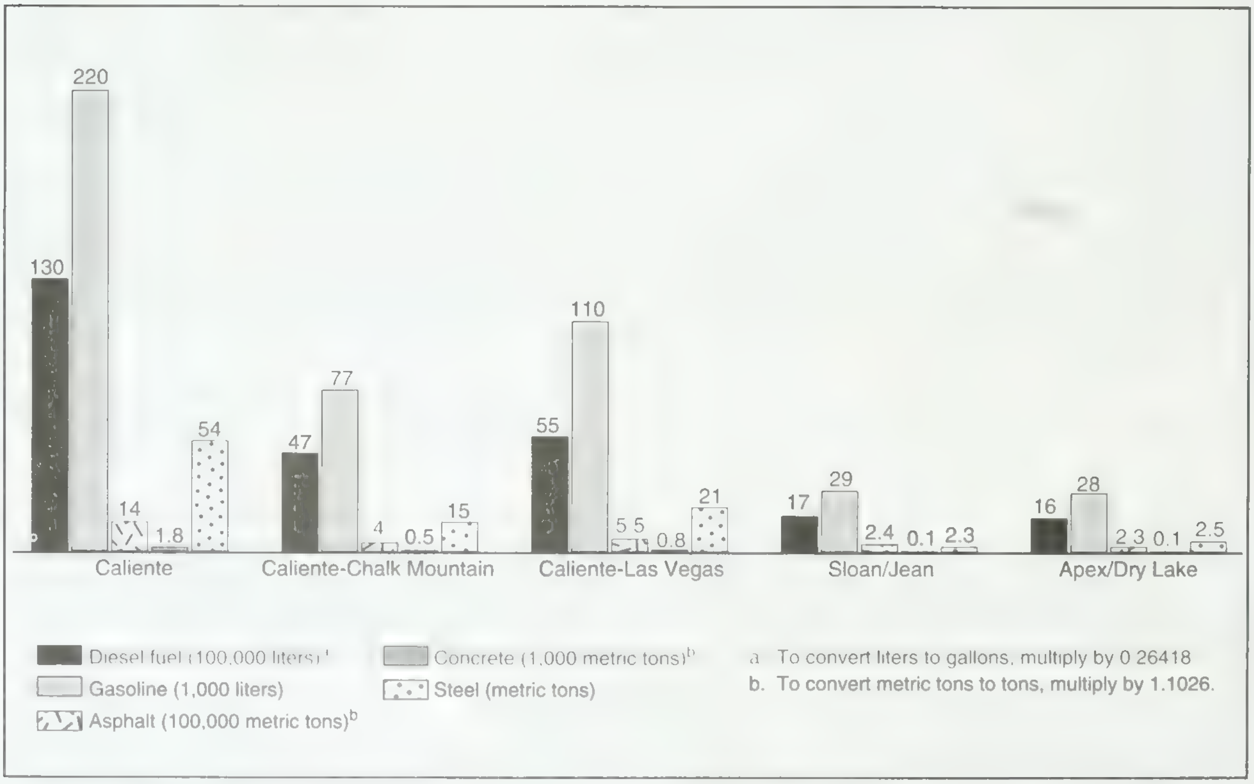


Figure 6-7. Utility, energy, and material use for upgrading of Nevada highways for heavy-haul truck use.

implementing alternatives. Potential visual resource (aesthetic) impacts were identified for the Jean rail corridor but these were determined to not be disproportionate. Potential impacts to cultural resources and noise impacts to Native American values have not been determined in all areas and may require further ethnographic study. However, no potentially disproportionately high and adverse impacts would occur in these areas for legal-weight truck transportation that would use existing highways. If DOE identified potentially high and adverse impacts for a corridor or route, it would mitigate them (as discussed in Chapter 9).

Because impacts to humans and other impacts that could affect minority or low-income populations or populations of Native Americans would not be disproportionately high and adverse, including mitigation as needed, an additional environmental justice analysis is not required. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

6.1.3 TRANSPORTATION OF OTHER MATERIALS AND PERSONNEL

Other types of transportation activities associated with the Proposed Action would involve the transportation of personnel and of materials other than the spent nuclear fuel and high-level radioactive waste discussed above. These other materials include construction materials and consumables for repository construction and operation, including disposal containers; waste including low-level waste, construction and demolition debris, sanitary and industrial solid waste, and hazardous waste; and office and laboratory supplies, mail, and laboratory samples.

Detailed analyses of the impacts of these transportation activities are provided in Appendix J. Overall, transportation of these materials and personnel could result in as many as 8 additional traffic fatalities. During operations, the additional traffic in the Las Vegas Valley would result in increased emissions of carbon monoxide. Because the Las Vegas Valley is a nonattainment area for carbon monoxide, an air quality conformity analysis may be required because estimated emissions are near the General Conformity Rule emission threshold (40 CFR Part 93). Impacts in other environmental resource areas would be unlikely to occur.

6.2 National Transportation

This section describes national transportation impacts from shipping spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites throughout the United States to the proposed Yucca Mountain Repository. This section includes the following:

- Definition and an overview of the analysis scenarios (Section 6.2.1)
- Impacts to workers and the public from spent nuclear fuel and high-level radioactive waste loading operations at commercial and DOE sites (Section 6.2.2)
- Potential incident-free (routine) radiological impacts and vehicle emission impacts (Section 6.2.3)
- Potential accident scenario impacts (Section 6.2.4)

National transportation of spent nuclear fuel and high-level radioactive waste, which would use existing highways and railroads, would average 14.2 million truck kilometers (8.8 million miles) per year for the mostly truck case and 3.5 million railcar kilometers (2.2 million miles) per year for the mostly rail case. Barges used to ship rail casks to nearby railheads from commercial sites not served by a railroad could travel an average of as much as 10,700 kilometers (6,650 miles) per year. The national yearly average for total highway and railroad traffic is 186 billion truck kilometers (116 billion miles) and 49 billion railcar

kilometers (30 billion miles) (BTS 1998, page 5)]. Spent nuclear fuel and high-level radioactive waste transportation would represent a very small fraction of the total national highway and railroad traffic (0.008 percent of truck kilometers and 0.007 percent of railcar kilometers). Domestic waterborne trade in 1995 accounted for about 1 billion metric tons (910 million tons) (MARAD 1998, all). This represents about 1 million barge shipments per year. Thus, shipments of spent nuclear fuel by barge would only be a very small fraction of the total annual domestic waterborne commerce.

With the exception of occupational and public health and safety impacts, which are evaluated in this section, the environmental impacts of this small fraction of all national transportation would be very small in comparison to the impacts of other nationwide transportation activities. Thus, the national transportation of spent nuclear fuel and high-level radioactive waste would have very small impacts on land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; utilities, energy, and materials; or waste management.

Radiological impacts of accidents on biological resources would be very small. The analysis focused the impacts from accidents on human health and safety. A severe accident scenario, such as the maximum reasonably foreseeable accident scenarios discussed in Section 6.2.4.2, that would cause a release of contaminated materials would be very unlikely. The probabilities of the severe accident scenarios discussed in Section 6.2.4.2 are less than 2 in 10 million per year for both the mostly legal-weight truck and mostly rail transportation scenarios. Because of the low probability of occurrence, an accident scenario during the transport of spent nuclear fuel and high-level radioactive waste would be unlikely to cause adverse impacts to any endangered or threatened species, and impacts to other plants and animals would be small. Therefore, the analysis did not evaluate the impacts for these environmental parameters for national transportation activities further.

6.2.1 ANALYSIS SCENARIOS AND METHODS

Under the mostly legal-weight truck scenario for national transportation, DOE would transport shipments (with the exception of naval spent nuclear fuel and possibly some DOE high-level radioactive waste) by legal-weight truck to Nevada. Naval spent nuclear fuel would be shipped by rail from the Idaho National Engineering and Environmental Laboratory. Under the mostly-legal weight truck scenario, DOE assumed that some shipments of DOE high-level radioactive waste would use overweight trucks. With the exception of permit requirements and operating restrictions, the vehicles for these shipments would be similar to legal-weight truck shipments but might weigh as much as 52,200 kilograms (115,000 pounds).

MOSTLY LEGAL-WEIGHT TRUCK AND MOSTLY RAIL SCENARIOS

The Department does not anticipate that either the mostly legal-weight truck or the mostly rail scenario represents the actual mix of truck or rail transportation modes it would use. Nonetheless, DOE used these scenarios as a basis for the analysis of potential impacts to ensure the analysis addressed the range of possible transportation impacts. Thus, the estimated numbers of shipments for the mostly legal-weight truck and mostly rail scenarios represent only the two extremes in the possible mix of transportation modes. Therefore, the analysis provides estimates that cover the range of potential impacts to human health and safety and to the environment for the transportation modes DOE could use for the Proposed Action.

States routinely issue special permits for trucks weighing up to 58,600 kilograms (129,000 pounds). Figure 6-8 shows the relationship of Interstate Highways, many of which would be preferred routes (see 49 CFR 397.101) for legal-weight truck shipments, and the locations of the commercial and DOE sites and Yucca Mountain.

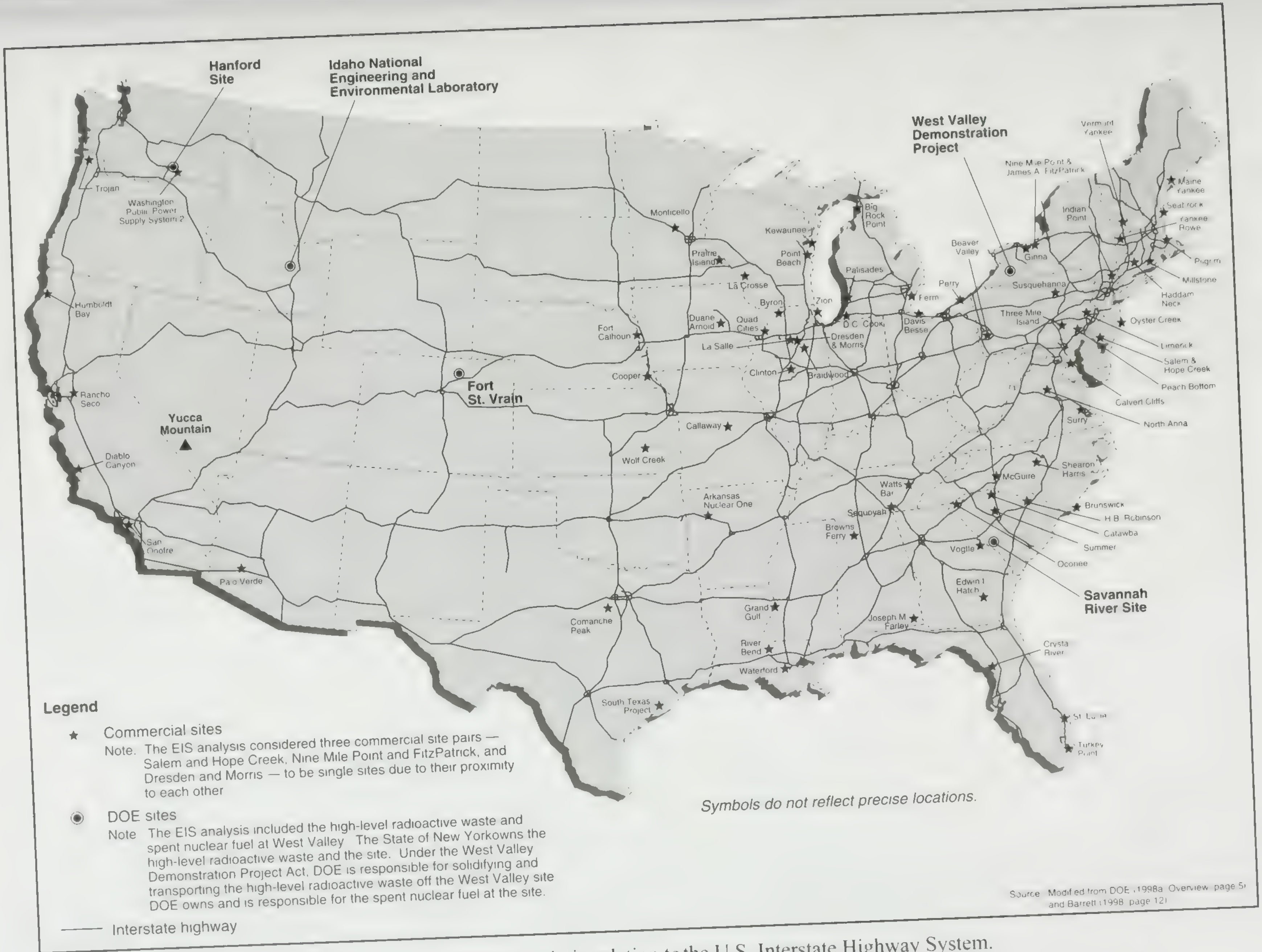


Figure 6-8. Commercial and DOE sites and Yucca Mountain in relation tothe U.S. Interstate Highway System.

Under the national transportation mostly rail scenario, DOE would transport shipments (with the exception of commercial spent nuclear fuel at 9 sites that do not have the capability to load a rail cask) by rail to Nevada. In addition, this scenario assumes that 19 commercial sites that have the capability to handle and load rail casks, but that do not have railroad service, would make shipments to nearby railheads by barge or heavy-haul truck. Barge shipments of rail casks containing spent nuclear fuel could be possible from 14 commercial sites that are on or near navigable waterways. Figure 6-9 shows the relationship of mainline railroads, many of which would be used for rail shipments, and the locations of the commercial and DOE sites and Yucca Mountain.

This section evaluates radiological and nonradiological impacts to workers and the public from routine transportation operations and from accidents. DOE used a number of computer models and programs to estimate these impacts; Appendix J describes the analysis assumptions and models.

The CALVIN model (TRW 1998l, page 2 to 22) was used to estimate the number of shipments of commercial spent nuclear fuel for both the mostly legal-weight truck and mostly rail scenarios. The CALVIN program used commercial spent nuclear fuel inventories and characteristics from the *Report on the Status of the Final 1995 RW-859 Data Set* (DOE 1996i, all) (see Appendix A) to estimate the number of shipments. For DOE spent nuclear fuel and high-level radioactive waste, the analysis used inventories and characteristics for materials to be shipped under the Proposed Action that were reported by the DOE sites in 1998 (see Appendix A) to estimate the number of shipments. Chapter 2, Section 2.1.2, and Appendix J discuss the number of shipments.

The transportation analyses used the following computer programs:

- HIGHWAY (Johnson et al. 1993a, all) to identify the highway routes that it could use to transport spent nuclear fuel and high-level radioactive waste. All of the routes would satisfy U.S. Department of Transportation route selection regulations.
- INTERLINE (Johnson et al. 1993b, all) to identify rail and barge routes for the analysis.
- RADTRAN4 (Neuhauser and Kanipe 1992, all) to estimate radiological dose risk to populations and transportation workers during routine operations. This program also estimated radiological dose risks to populations and transportation workers from accidents.
- RISKIND (Yuan et al. 1995, all) to estimate radiological doses to the maximally exposed individuals and to the population during routine transportation. This program also estimated radiological doses to the maximally exposed individuals and to the population from transportation accidents.

6.2.2 IMPACTS FROM LOADING OPERATIONS

This section describes potential impacts from loading spent nuclear fuel and high-level radioactive waste in transportation casks and on transportation vehicles at the 72 commercial and 5 DOE sites. It also describes methods for estimating radiological and industrial hazard impacts from routine loading operations and radiological impacts of loading accidents to workers and members of the public. During loading operations, radiological impacts to workers could occur from normal operations and accidents. In addition, workers could experience impacts from industrial hazards. Members of the public could experience radiological impacts if a loading accident occurred but would not experience impacts from industrial hazards, including hazards associated with nonradioactive hazardous materials. Nonradioactive hazardous materials would be used only in small quantities, if at all, in loading operations. Chapter 4 addresses impacts from unloading operations at the repository.

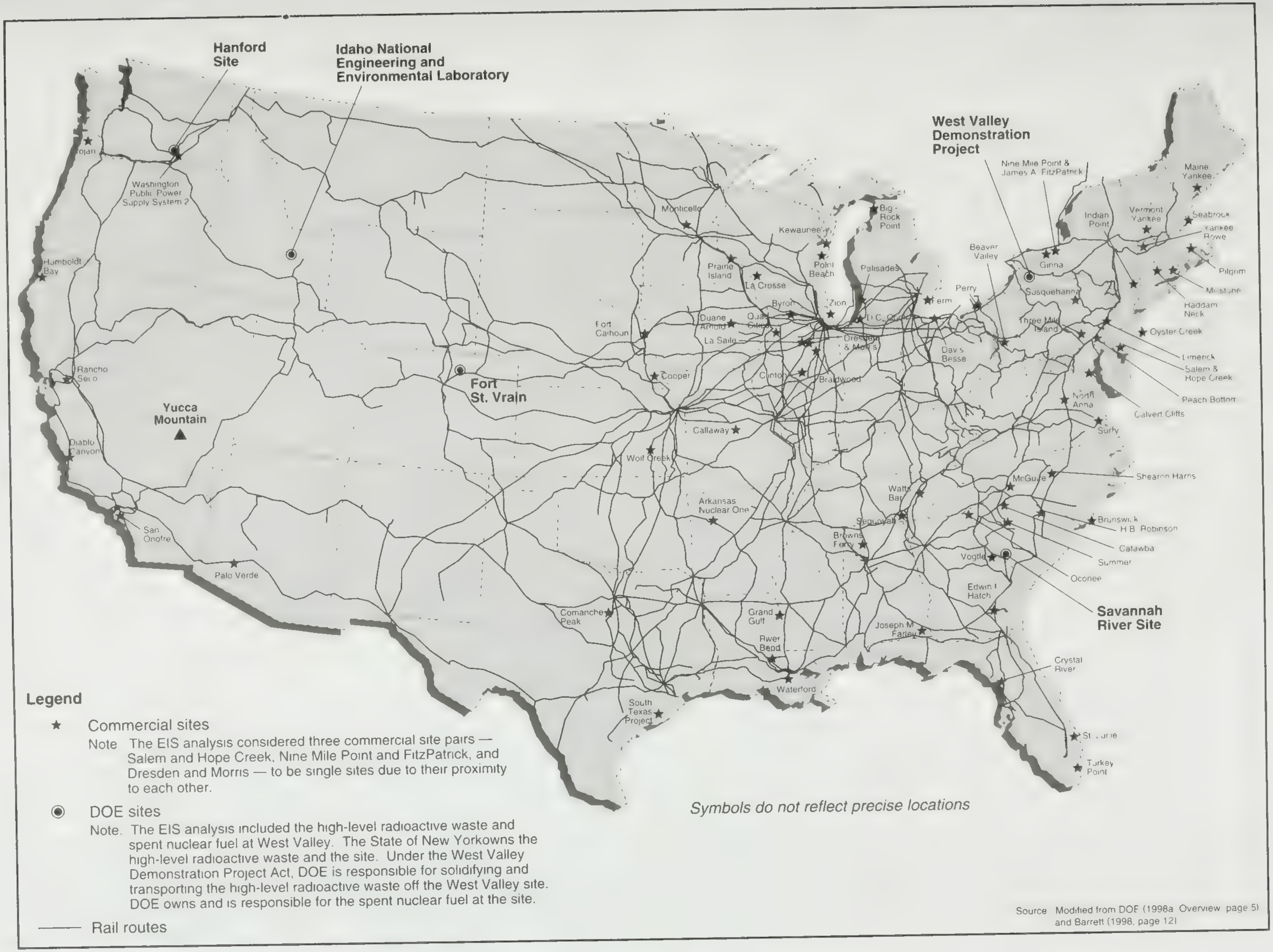


Figure 6-9. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

6.2.2.1 Radiological Impacts of Routine Operations

Radiological impacts to members of the public from routine operations would be very small. An earlier DOE analysis estimated that public dose from loading operations would be less than 0.001 person-rem per metric ton of uranium loaded (DOE 1986b, Volume 2, Figure 2.9, page 2.42) but did not provide a definite estimated lower value (see Appendix J for more information). Therefore, to be conservative this analysis estimated the dose to the public from loading operations by multiplying the value of 0.001 person-rem per metric ton uranium by the 70,000 metric tons of spent nuclear fuel and high-level radioactive waste DOE would transport under the Proposed Action. [DOE (1986b, Volume 2, all) uses the term "metric ton uranium," which is essentially the same as metric tons of heavy metal for commercial spent nuclear fuel.] The resulting population dose is 70 person-rem, which, based on conversion factors recommended by the International Commission on Radiological Protection, would result in 0.04 latent cancer fatality.

Table 6-3 lists estimated involved worker impacts from loading spent nuclear fuel at commercial sites and loading DOE spent nuclear fuel and high-level radioactive waste at DOE facilities for shipment to the Yucca Mountain site under the Proposed Action. The impacts assume worker rotation and other administrative actions would follow guidance similar to that in the DOE *Radiological Control Manual* (DOE 1994c, Article 211) that would limit doses to individual workers to 500 millirem per year. The maximum individual dose would be 12 rem over the 24 years of loading operations for individuals who worked the entire duration of repository operations. The estimated probability of a latent cancer fatality for an involved worker from this dose would be about 0.005 (5 chances in 1,000).

Table 6-3. Estimated radiological impacts to involved workers from loading operations.[a]

Impact	Mostly rail	Mostly legal-weight truck
Maximally exposed individual		
Dose (rem)	12	12
Probability of LCF[b]	0.005	0.005
Involved worker population[c]		
Dose (person-rem)	5,200	14,200
Number of LCFs	2	6

a. Numbers are rounded.
b. LCF = latent cancer fatality.
c. All involved workers at all facilities, preparing about 13,400 shipments under the mostly rail scenario and about 49,800 shipments under the mostly legal-weight truck scenario over 24 years.

As many as 2 latent cancer fatalities from the mostly rail scenario and about 6 latent cancer fatalities from the legal-weight truck scenario could result in the involved worker population over 24 years. The mostly legal-weight truck scenario would result in more potential impacts than the mostly rail scenario because of the increased exposure time needed to load more transportation casks. DOE expects impacts to noninvolved workers to be even smaller than those to involved workers. Using information from the earlier studies (Schneider et al. 1987, all; Smith, Daling, and Faletti 1992, all; DOE 1986b, Volume 2, all), DOE estimated 0.04 latent cancer fatality to members of the public from routine loading operations.

6.2.2.2 Impacts from Industrial Hazards

Table 6-4 lists estimated impacts to involved workers from industrial hazards over 24 years of loading operations at the 77 sites. Fatalities from industrial hazards would be unlikely from loading activities under either national transportation scenario. The mostly legal-weight truck scenario would have about double the estimated number of total recordable cases and lost workday cases of the mostly rail scenario because there would be more shipments and more work time (full-time work years). Using the assumption that the noninvolved workforce would be 25 percent of the number of involved workers, the analysis determined that impacts to noninvolved workers would be about 25 percent of those listed in Table 6-4. In addition to industrial safety impacts, traffic fatality impacts to commuting workers during commuting and operations were estimated. Traffic involving commuting workers could result in 0.5 fatality under the mostly legal-weight truck scenario and 0.2 fatality under the mostly rail scenario.

Table 6-4. Impacts to involved workers[a] from industrial hazards during loading operations.[b]

Impact	Mostly rail	Mostly legal-weight truck
Total recordable cases[c]	65	150
Lost workdays[d]	29	66
Fatalities[e]	0.06	0.14

a. Includes all involved workers at all facilities during 24 years of repository operations. During the 24 years of shipments to the proposed repository, these workers would put in 1,700 work years (2,080 hours per work year) preparing about 13,400 shipments under the mostly rail scenario and 3,900 work years preparing about 49,500 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments under the mostly legal-weight truck scenario. Impacts in the noninvolved workforce would be about 25 percent of those listed.

b. Numbers are rounded to two significant digits.

c. Total recordable cases (injury and illness) based on a 1992-1997 DOE site loss incident rate of 0.03 (DOE 1999c, DOE and Contractor Injury and Illness Experience).

d. Lost workday cases based on a 1992-1997 DOE site loss incident rate of 0.013.

e. Fatalities based on a 1988-1997 DOE site loss incident rate of 0.000029.

6.2.3 NATIONAL TRANSPORTATION IMPACTS

The following sections discuss the impacts of transporting spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository under the mostly legal-weight truck and mostly rail scenarios. The analysis in this section addresses the impacts of incident-free transportation. Section 6.2.4 discusses accidents, and Appendix J contains the details on the analysis and its assumptions.

6.2.3.1 Impacts from Incident-Free Transportation – National Mostly Legal-Weight Truck Transportation Scenario

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals for incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly-legal weight truck scenario.

Incident-Free Radiological Impacts to Populations. Table 6-5 lists the incident-free population dose and latent cancer fatalities to workers and the public for the mostly legal-weight truck scenario. The impacts include those for the shipment of naval spent nuclear fuel by rail to Nevada, intermodal transfer of rail casks to heavy-haul trucks, and subsequent heavy-haul transportation to the proposed repository. Section 6.3.3 and Appendix J contain additional information on worker impacts from intermodal transfer operations. Worker impacts would include radiological exposures of security escorts for legal-weight truck, rail, and heavy-haul truck shipments and from the transfer of naval spent nuclear fuel shipments from rail to heavy-haul truck. The collective dose to the security escorts, who would travel in separate vehicles, would be about 250 person-rem for legal-weight truck shipments. Doses to escorts of rail shipments of naval spent nuclear fuel, who would travel in railcars in sight of but separated from the cask cars, followed by escorted heavy-haul truck shipments in Nevada would be about 27 person-rem. (See Appendix J, Section J.1.3.2.2.2.)

Table 6-5. Population doses and impacts from incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]
Involved workers		
Collective dose (person-rem)	11,000	65
Estimated LCFs[c]	4.5	0.03
Public		
Collective dose (person-rem)	35,000	45
Estimated LCFs	18	0.02

a. Impacts are totals for shipments over 24 years.

b. Includes impacts from intermodal transfer operations (see Section 6.3.3.1).

c. LCF = latent cancer fatality.

The estimated radiological impacts would be 5 latent cancer fatalities for workers and 18 latent cancer fatalities for members of the public for the 24 years of operation. The population within 800 meters

(0.5 mile) of routes would be about 7.2 million. About 1.6 million members of this population would be likely to incur fatal cancers from all other causes (ACS 1998, page 10).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-6 lists estimates of doses and radiological impacts for maximally exposed individuals for the legal-weight truck scenario (which considers drivers and security escorts). The risks are calculated for the 24 years of shipment activities. Appendix J discusses analysis methods and assumptions. State inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste and transportation vehicle operating crews would receive the highest annual radiation doses.

Table 6-6. Estimated doses and radiological impacts to maximally exposed individuals for national mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (including driver)	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00006
Public		
Resident along route	0.0054	0.000003
Person in traffic jam	0.04[d]	0.00002
Person at service station	2.4[e]	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Assumes 2-rem-per-year dose limit.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations.

Impacts to the maximally exposed individuals in the general public would be very low. The highest impacts, to a service station employee, would still be very low (Table 6-6); the analysis estimated that a maximally exposed individual at a service station would receive 2.4 rem over 24 years under the legal-weight truck scenario. This estimate conservatively assumed the person would be exposed to 430 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,100 legal-weight truck shipments per year, about 430 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 430.

Impacts from Vehicle Emissions. Table 6-7 lists the estimated number of fatalities that vehicle emissions from shipments to the Yucca Mountain site would cause. These potential impacts would result principally from exposure to increases in levels of pollutants in urban areas where the additional pollutants would come from vehicles transporting spent nuclear fuel and high-level radioactive waste and the accompanying escort vehicles. In the context of the number of vehicle kilometers from shipments to the Yucca Mountain site, these emissions would be very small in comparison to the emissions from other vehicles.

6.2.3.2 Impacts from Incident-Free Transportation – National Mostly Rail Transportation Scenario

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for

Table 6-7. Population health impacts from vehicle emissions during incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel	Total[b]
Estimated vehicle emission-related fatalities	0.6	0.002	0.6

a. Impacts are totals for shipments over 24 years.
b. Total differs due to rounding.

the mostly rail national transportation scenario. In addition, it identifies impacts of legal-weight truck shipments that would occur under the mostly rail scenario for the nine commercial sites that do not have the capability to load rail casks (about 2,600 legal-weight truck shipments over 24 years).

For this analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in Nevada to transport rail casks to and from the repository. Accordingly, the results indicate the range of impacts for the rail and heavy-haul truck implementing alternatives that DOE could use for transportation to the repository after rail shipments arrived in Nevada. Section 6.3 and Appendix J present more information on the analysis of the environmental impacts of the Nevada rail and heavy-haul implementing alternatives. Appendix J also presents a comparison of the effects of using dedicated trains or general freight services for rail shipments.

The mostly rail scenario assumes that the 19 commercial sites not served by a railroad but with the capability to handle rail casks would use heavy-haul trucks to transport the casks to railheads for transfer to railcars. In addition, 14 of the 19 sites are adjacent to navigable waterways. At some of the 14 sites on navigable waterways, barges could be used for the initial trip segments (see Appendix J). The impacts estimated by the analysis include the impacts of heavy-haul truck or barge shipments of rail casks from the 19 sites to nearby railheads.

The analysis assumed that the truck shipments of spent nuclear fuel and high-level radioactive waste would make periodic stops for state inspections, changes of drivers, rest, and fuel. Rail shipments would also make periodic stops. However, the assumed frequency of the stops and the numbers of people nearby would be different from those for truck shipments and would result in a lower dose.

Incident-Free Radiological Impacts to Populations. Table 6-8 lists incident-free radiological impacts that would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste under the mostly rail national transportation scenario. Because national impacts would result from transportation from the commercial and DOE sites to the repository, they include impacts from a Nevada rail or heavy-haul truck implementing alternative. For the case in which rail shipments would continue in Nevada, total impacts to members of the general public would differ depending on the implementing alternative (see Section 6.3.2 for additional details). The range of values listed in Table 6-8 includes the range of impacts from the Nevada implementing alternatives.

Impacts to members of the public from legal-weight truck shipments under the mostly rail transportation scenario would be greater than those for rail shipments. About 90 percent of the estimated impacts would involve persons at in-transit stops.

About 2 latent cancer fatalities would result from shipments of spent nuclear fuel and high-level radioactive waste under the mostly rail scenario over 24 years. The latent cancer fatalities would occur over the lifetimes of individuals in the exposed population. The population within 800 meters (0.5 mile) of routes in which these 2 fatalities would occur would be approximately 13 million. Approximately 2.9 million members of this population would incur fatal cancers from all other causes (ACS 1998, page 10).

Table 6-8. Population doses and radiological impacts from incident-free transportation for national mostly rail scenario.[a]

Category	Legal-weight truck shipments	Rail shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	850	1,100 - 1,500	1,900 - 2,300
Estimated LCFs[d]	0.34	0.43 - 0.59	0.77 - 0.93
Public			
Collective dose (person-rem)	2,400	880 - 2,600	3,300 - 5,000
Estimated LCFs	1.2	0.44 - 1.3	1.6 - 2.5

a. Impacts are totals for 24 years (2010 to 2033).
b. Barge transportation to a railhead on navigable waterways could be used for transportation from 14 commercial sites that do not have rail service but can load a rail cask. See Appendix J.
c. Totals might differ from sums of values due to rounding.
d. LCF = latent cancer fatality.

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-9 lists the results of risk calculations for maximally exposed individuals for the mostly rail transportation scenario over 24 years. Truck and rail crew members would receive the highest doses. The mostly rail scenario would require transport crews for legal-weight trucks (2,600 total shipments over 24 years) and for rail shipments. Individual crew members who operated legal-weight trucks and escorts for rail shipments could be exposed to as much as 48 rem over 24 years of operations (maximum exposure of 2 rem each year). State inspectors who would conduct frequent inspections of rail shipments could receive annual radiation doses as high as 1.5 rem.

Table 6-9. Estimated doses and radiological impacts to maximally exposed individuals for national mostly rail scenario.[a,b]

Receptor	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck, or legal-weight truck)	48[c]	0.02
Inspector (rail)	35	0.014
Railyard crew member	4.4	0.0018
Public		
Resident along route (rail)	0.003	0.000002
Person in traffic jam (legal-weight truck)	0.04	0.00002
Person at service station (legal-weight truck)	0.14	0.00007
Resident near rail stop	0.31	0.00016

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years.
c. Assumes 2-rem-per-year dose limit.

Impacts from Vehicle Emissions. Fewer than 1 fatality (0.3) would result from exposure to vehicle emissions over 24 years under the mostly rail scenario. This potential increase would result principally from exposure of people in urban areas to very small increases in levels of pollutants caused by vehicles transporting spent nuclear fuel and high-level radioactive waste.

6.2.4 ACCIDENT SCENARIOS

6.2.4.1 Loading Accident Scenarios

The analysis used existing information from several different sources (TRW 1994b, all; CP&L 1989, all; PGE 1996, all; DOE 1997b, all) to estimate potential radiological impacts from accidents involving the loading of spent nuclear fuel or high-level radioactive waste for shipment and handling of shipping casks.

As summarized below, the results in these sources indicate that there would be no or very small potential radiological consequences from accidents in all cases. Appendix J presents a description of typical operations for loading spent nuclear fuel in a shipping cask at a commercial facility.

Lift-handling incidents involving spent nuclear fuel in a transfer facility would have an estimated probability of 0.0001 (1 in 10,000) per handling operation (TRW 1994b, pages 3 to 8). The estimated collective dose to workers from the incidents would be no more than 0.1 person-rem, and it would be much less to the public.

The total number of high-level radioactive waste canisters potentially handled would be approximately the same as the number of spent nuclear fuel canisters, and handling operations would be similar. DOE expects the consequences of handling incidents that involved high-level radioactive waste would be less than those involving spent nuclear fuel (Kappes 1998, page 3). Thus, impacts from high-level waste handling would be less than the estimated 0.1-person-rem from a spent nuclear fuel handling accident.

Reports on independent spent fuel storage installations and previous DOE analyses provide further evidence of the low probable impacts associated with a loading accident. Safety analysis reports prepared for independent spent fuel storage installations at the Trojan Nuclear Station and the Brunswick Steam Electric Plant concluded that there would be no or low radiological consequences from accidents that could occur at such facilities (PGE 1996, Section 8.2; CP&L 1989, Section 8.2). This analysis examined the potential magnitude of impacts from spent nuclear fuel storage facility operations. Only one event (loss of air outlet shielding blocks on a horizontal storage module, which a tornado projectile could cause) could result in a dose to an offsite member of the public. The estimated dose to an individual at a distance of 200 meters (656 feet) would be 0.0013 rem (a 0.0000007 probability 7 in 10 million of a latent cancer fatality) from direct and air-scattered (skyshine) radiation for a single horizontal storage module. The estimated dose to involved workers to recover from the event would be less than 0.09 person-rem (0.00002 latent cancer fatality). No other credible accidents involving a horizontal storage module had associated radiological consequences (NUTECH 1989, Section 10.2.3). Similarly, previous DOE analyses (DOE 1997b, all; TRW 1994b, all) indicate that radiological consequences from accidents involving spent nuclear fuel and high-level radioactive waste management activities would be very small (Table 6-10). The low consequences listed in Table 6-10 are consistent with the results from an earlier DOE analysis (DOE 1986b, Volume 2, page xvii).

6.2.4.2 Transportation Accident Scenarios

Accidents could occur during the transportation of spent nuclear fuel and high-level radioactive waste. This section describes the risks and impacts to the public and workers from accident scenarios that are highly unlikely but that would have severe consequences (called *maximum reasonably foreseeable accident scenarios*) to accident scenarios that are more likely but that would have less severe consequences. The impacts would include those to the population and to hypothetical maximally exposed individuals. The following paragraphs describe the analysis approach. Appendix J contains more details.

The analysis did not address accident impacts to workers apart from impacts to the public. For example, fatalities from train and truck accident scenarios would include fatalities for vehicle operators. The collective radiological risk from accidents to highway vehicle and train crews would be much less than for the public because of the large difference in the numbers of individuals that could be affected. In addition, based on national accident statistics, motor carrier and train operators are much less likely to be fatalities in accidents than operators of other vehicles (NHTSA 1998, page 30).

The specific number, location, and severity of an accident can be predicted only in general terms of the likelihood of occurrence (the probability). Similarly, the weather conditions at the time an accident

Table 6-10. Radiological consequences of accidents associated with handling and loading operations.

Affected group	Impact (per year)[a]	24-year impact	Source
Involved workers			
Maximally exposed involved worker			
Dose (rem)	0.0005	0.01	--[b]
Probability of LCF[c]	0.0000002	0.000005	--
Worker population			
Collective dose (person-rem)	0.1	2.4	TRW (1994b, pages 3 to 8)
Number of LCFs	0.00004	0.001	--
Noninvolved workers			
Maximally exposed noninvolved worker			
Dose (rem)	0.0002	0.005	--
Probability of LCF	0.00000005	0.000001	--
Worker population	No information available		
Public			
Maximally exposed individual			
Dose (rem)	0.0013	0.03	NUTECH (1989, Section 10.2.3)
Probability of LCF	0.0000007	0.00002	--
Population			
Collective dose (person-rem)	0.000074	0.002	TRW (1994b, page 3-8)
Number of LCFs	0.00000004	0.000001	--

a. Average annual impact for 24 years.
b. -- = determined by analysis.
c. LCF = latent cancer fatality.

occurs cannot be precisely predicted. Therefore, the EIS analysis evaluated a variety of accident scenarios and conditions to understand the influence of various conditions on environmental impacts. The analysis of impacts to populations along routes assumed that an accident could occur at any location along a route.

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS

Maximum reasonably foreseeable impacts from accident scenarios for the transportation of spent nuclear fuel and high-level radioactive waste would be characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest reasonably foreseeable consequences. For postulated accident scenarios such as these, the forces and heat would exceed the design limits of transportation cask structures and materials. (The performance of transportation casks was demonstrated through a combination of tests and analyses.) In addition, these forces and heat would be applied to the structures and surfaces of a cask in a way that would cause the greatest damage and bring about releases of radioactive materials to the environment. The most severe accident scenarios analyzed in this chapter would release radioactive material. These accident scenarios correspond to those in the highest accident severity category, which represent events that would be very unlikely but, if they occurred, would result in human health effect consequences.

In general, this EIS considers accidents with conditions that have a chance of occurring more often than 1 in 10 million times in a year to be reasonably foreseeable. Accidents and conditions less likely than this are not considered to be reasonably foreseeable.

THE MODAL STUDY

Factors other than the environment can cause uncertainties in the prediction of accident impacts. Uncertainty can be the result of limited data and the computer programs used to predict accident impacts. To assess potential impacts of severe highway and railroad transportation accident scenarios, DOE used conservative estimates developed for the *Shipping Container Response to Severe Highway and Railway Accident Conditions* [Fischer et al. (1987, all); also called the *Modal Study*] for fractions of shipping cask contents (spent nuclear fuel or high-level radioactive waste) that such accident scenarios could release to the environment. The Modal Study was a large-scale, multiyear study of the degree of safety provided by shipping casks certified by the U.S. Nuclear Regulatory Commission for the transportation of spent nuclear fuel. The Lawrence Livermore National Laboratory conducted the study, which the Commission sponsored. One of the study's major purposes was to assess the adequacy of the Commission regulations for the packaging and transportation of radioactive materials.

The State of Nevada and the Nevada Nuclear Waste Project Office have commented that the study's projections of amounts of radioactive materials that accident scenarios would release and the probabilities of release in severe accident scenarios might significantly underestimate releases and probabilities in real accidents. The Nuclear Waste Project Office based its comments on its assessment that:

- Cask design and accident scenario parameters were significantly oversimplified.
- A great deal of data was "created" to fill missing data on the probabilities of different accident conditions.
- The interactions of physical stresses in shipping cask structures were not fully analyzed.
- Failure to examine the impact of human error limited the applicability of the analysis to the real world.
- Computer simulations of cask impacts on surfaces did not replicate a phenomenon known as "slap down."
- The treatment of spent fuel damage was too simplistic.
- The portrayal of the spent fuel was deficient.
- Available data on cladding and fuel damage were not referenced or utilized.

The Nuclear Waste Project Office did not suggest the use of alternative analyses or models and did not offer differing values for use in estimating consequences or risks of severe accidents. In addition, its comments did not identify examples of actual accident conditions and damage to structures that could support different values for release fractions or release probabilities.

In responding to comments from an independent peer group that the Nuclear Regulatory Commission asked to review the study, the authors of the Modal Study observed that a detailed analysis would reduce conservatism and show that the actual radiological hazard is lower than the hazard calculated in the study.

An assessment of uncertainty in the Modal Study recognized many of the limitations that the Nuclear Waste Project Office pointed out—limited data and information on past accidents, limitations of using mathematical models to model complex physical phenomena, and limitations on the resources to perform the analysis. Recognizing the uncertainties, the study authors stated that they tried to use realistic, yet conservative, models and probabilities. They observed that if the objective had been the precise definition of spent fuel transportation risks, they would need many improvements to calculate the probability and radioactive release estimates and to quantify the uncertainties in the estimates. The improvements would include tests to benchmark computer models; more sophisticated models of rock surfaces; improved probability distributions of accident parameters; and the consideration of human factors. These modifications were not considered because the objective was to estimate the level of safety in the shipment of spent fuel using casks licensed to Nuclear Regulatory Commission standards, and because the radiological risk in spent fuel shipments would be a small component of the total risks associated with the shipments. Therefore, DOE concluded that the most appropriate data available for the analysis of severe accidents are in the Modal Study.

TRANSPORTATION EMERGENCIES

DOE would, as requested, assist state, tribal, and local governments in several ways to reduce the consequences of accidents related to the transportation of spent nuclear fuel and high-level radioactive waste. Under Section 180(c) of the Nuclear Waste Policy Act, the Department would provide technical assistance and funding to train state, local, and tribal public safety officials in relation to such transportation. The training would cover safe transport procedures and emergency response. DOE would also require its transportation contractors to comply with ANSI N14.27-1986(R1993), *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Truckload Quantities of Radioactive Materials*. This standard requires the preparation of an emergency response plan and describes appropriate provisions of information and assistance to emergency responders. The standard also requires the carrier to provide appropriate resources for dealing with the consequences of the accident including isolating and cleaning up spills, and to maintain working contact with the responsible governmental authority until the latter has declared the incident to be satisfactorily resolved and closed. In addition, DOE maintains an active emergency response program through eight Regional Coordinating Offices across the United States. These offices are capable of responding to transportation radiological emergencies and are on call 24 hours a day. They respond to requests for radiological assistance from state or tribal authorities. Other DOE programs have provided training for transportation emergencies for many areas (for example, Colorado and South Carolina to support preparation or transportation for the Foreign Research Reactor and Waste Isolation Pilot Plant programs).

The analysis considered six categories of increasingly severe and increasingly unlikely accident scenarios. Appendix J describes those categories and their derivations. Further, the analysis hypothesized one accident scenario to represent each category, along with a corresponding projection for the amount of radioactive material the accident scenario would release from a transportation cask. In addition, the analysis estimated impacts of postulated releases from accident scenarios in three population zones—urban, suburban, and rural—under two meteorological (weather) conditions—stable (slowly dispersing) conditions that would not be exceeded (more still) about 95 percent of the time and neutral (moving air) conditions that would not be exceeded about 50 percent of the time. The analysis determined radiological risks from possible accident scenarios by multiplying the estimated impacts of each accident type by the likelihood of the accident scenario occurring in a population zone under a set of weather conditions, and summing the results for the 36 possible combinations of accident scenarios, population zones, and weather conditions. The analysis determined the likelihood that an accident scenario would occur in a population zone by using state-specific accident data, the lengths of routes in the population zones in states through which the routes would pass, and the numbers of shipments that would use the routes. Four of the scenarios would not have a probability greater than 1 chance in 10 million, so they were not considered further.

In addition, the analysis estimated impacts from an unlikely but severe accident scenario called a *maximum reasonably foreseeable accident* scenario to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accident scenarios, the analysis selected the accident scenario from the 32 possible combinations of weather conditions, population zones, and transportation mode that would have a likelihood greater than 1 in 10 million per year and would have the greatest consequences. For analysis of maximum reasonably foreseeable accident scenarios, the number of possible accident scenario combinations discussed above was reduced from 32 to 23 because suburban and urban population zones were considered jointly (see Appendix J).

6.2.4.2.1 *Impacts from Accidents – National Mostly Legal-Weight Truck Scenario*

This section summarizes the potential impacts and risks associated with accidents under the legal-weight truck scenario. The impacts and risks include those associated with the legal-weight truck and rail shipments to Nevada plus the transfer of the spent nuclear fuel and high-level waste to heavy-haul trucks and its transportation in Nevada. The section summarizes radiological impacts for six accident scenario categories, under two types of weather conditions, and in three population densities (urban, suburban, and rural), in terms of a collective dose risk and consequence (latent cancer fatalities). It describes the potential impacts from the maximum reasonably foreseeable accident scenario separately. It also describes nonradiological impacts in terms of accident fatalities.

Radiological Impacts to Populations from Accidents. The collective radiological accident dose risk as described in Appendix J, Section J.1.4.2.1, would be 134 person-rem for the population within 80 kilometers (50 miles) along the transportation routes. This calculated risk would be the total for 24 years of shipment operations (2010 to 2033). It would result in an estimated 0.07 latent cancer fatality, or approximately 7 chances in 100 of 1 latent cancer fatality for the population within 80 kilometers of the routes that the shipments would use. The accident risk for legal-weight truck shipments dominates the total risk, contributing more than 99.9 percent of the population dose and risk in comparison to the risk associated with the 300 proposed shipments of naval spent nuclear fuel.

Consequences of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized and rural population zones for both legal-weight truck and rail shipments under the mostly legal-weight truck scenario. The maximum reasonably foreseeable transportation accident scenario that would have the greatest consequences for the mostly legal-weight truck scenario would be a legal-weight truck accident under stable (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time) meteorological conditions in an urban area. Severe accidents in other population zones under stable or neutral weather conditions (atmospheric conditions that would not be exceeded 50 percent of the time) would have smaller consequences. The accident scenario assumes a breach of the shipping cask and the release of a portion of its contents to the air. This accident in combination with stable atmospheric conditions would be very unlikely (1.9 in 10 million per year). Table 6-11 summarizes the impacts of the accident scenario. This accident scenario could cause 5 latent cancer fatalities; in comparison, a population of 5 million within 80 kilometers (50 miles) of the center of a large U.S. metropolitan area such as that assumed in the analysis would be likely to experience more than 10,000 cancer fatalities each year from other causes (ACS 1998, page 10). For this accident scenario, the analysis projected that most of the dose to a population would come from inhalation, cloudshine, and groundshine sources. The maximally exposed individual, assumed to be about 360 meters (1,180 feet) from the accident, would receive a dose of about 3.9 rem (Table 6-11).

Table 6-11. Estimated radiological impacts of maximum reasonably foreseeable accident scenario for national mostly legal-weight truck scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident scenario probability (annual)	0.00000019 (about 1.9 in 10 million)
Impacts to population	
Population dose (person-rem)	9,400
Latent cancer fatalities	4.7
Impacts to maximally exposed individual	
Maximally exposed individual dose (rem)	3.9
Probability of a latent cancer fatality	0.002

Impacts from Traffic Accidents. Approximately 4 (3.9) traffic fatalities could occur in the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck national transportation scenario during the 24 years of operations for the Proposed Action. Essentially all of these fatalities would be from truck operations; none would occur from the 300 railcar shipments of naval spent nuclear fuel. The fatalities would be principally from traffic accidents; half would involve trucks transporting loaded casks to the repository and half would involve returning shipments of empty casks. The fatalities would occur over 24 years and approximately 350 million kilometers (220 million miles) of highway travel, which would include escort vehicle travel. Based on information extrapolated from the U.S. Department of Transportation Bureau of Transportation Statistics (BTS 1998, page 20), during the same 24-year period, about 1 million deaths would be likely to occur in traffic accidents on U.S. highways.

6.2.4.2.2 *Impacts from Accidents – National Mostly Rail Transportation Scenario*

This section discusses the results of the analysis of radiological impacts to populations and maximally exposed individuals and of traffic fatalities that would arise from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the national mostly rail transportation scenario.

DOE used the models and calculations described in Appendix J to estimate the impacts from rail accidents, and included impacts postulated to occur during the transportation of commercial spent nuclear fuel by legal-weight trucks from 9 commercial sites that do not have the capability to handle or load large rail casks. The analysis also included the impacts from accidents for heavy-haul truck or barge shipments to nearby railheads from 19 commercial sites that have the capability to load a rail cask but are not served by a railroad. DOE used the models and calculations described in Appendix J to estimate the impacts. Appendix J presents additional information on heavy-haul truck and barge transportation from the 19 commercial sites.

Accident Radiological Impacts for Populations. The collective radiological accident dose would be between 42 and 47 person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly rail transportation scenario. The range of 42 to 47 person-rem reflects differences in rail and heavy-haul truck implementing alternatives that DOE could use in Nevada. This is the total for 24 years of shipment operations. This population dose would be likely to cause 0.024 latent cancer fatality.

Radiological risks from accidents for the mostly rail scenario would include impacts associated with about 10,815 railcar shipments (one cask to a railcar) and 2,600 legal-weight truck shipments. The accident risk for the legal-weight truck shipments would be about 20 percent of the total population dose and risk for the mostly rail scenario. National rail transportation of spent nuclear fuel and high-level radioactive waste would account for the remaining 80 percent of the population dose and risk to the public.

Impacts of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized areas or rural population zones and under stable and neutral atmospheric conditions. The maximum reasonably foreseeable accident scenario under the mostly rail scenario would involve a release of a fraction of the contents of a rail cask in an urban area under stable meteorological conditions (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time), where atmospheric dispersion of contaminants would occur more slowly only 5 percent of the time. This accident scenario would have a likelihood of about 1.4 in 10 million per year, and would result in about 31 latent cancer fatalities in the population (Table 6-12). The maximally exposed individual, assumed to be about 360 meters (1,180 feet) from the accident, would receive a dose of about 26 rem (Table 6-12).

Impacts From Traffic Accidents. The analysis estimated that across the United States, approximately 4 (3.6) traffic and train accident fatalities could occur during transportation of spent nuclear fuel and high-level radioactive waste under the national mostly rail transportation scenario. Half of the fatalities would occur during the return of empty casks to commercial and DOE sites. Essentially all of the fatalities would involve train operations; about half would involve highway vehicles hit by trains. There would be about a 40-percent chance of 1 fatality from the 2,600 legal-weight truck shipments of commercial spent nuclear fuel. These fatalities could happen during the 24 years of transportation operations involving approximately 84 million kilometers (52 million miles) of railcar travel and 22 million kilometers (14 million miles) of highway travel. On the basis of data presented by the Bureau of Transportation Statistics (BTS 1998, page 20), during the same 24-year period, about 1 million people will die in traffic accidents on U.S. highways.

Table 6-12. Estimated impacts from maximum reasonably foreseeable accident scenario for national mostly rail transportation scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident probability	0.00000014 per year (about 1.4 in 10 million)
Impacts to populations	
Population dose (person-rem)	61,000
Latent cancer fatalities	31
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	26
Probability of a latent cancer fatality	0.013

6.2.4.2.3 *Impacts of Acts of Sabotage*

The analysis considered the impacts of successful sabotage attempts on a cask. A sabotage event cannot be characterized as a random event and was, therefore, not addressed in the same way as an accident, which would be random. However, the analysis evaluated the consequences of possible credible sabotage events and found them to be comparable with the impacts of maximum reasonably foreseeable accident events. A study conducted by Sandia National Laboratories (Luna, Neuhauser, and Vigil 1999, all) estimated the amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to the effects of two different high-energy density devices.

Devices considered in the Sandia study (Luna, Neuhauser, Vigil 1999, all) included possible devices that might be used in acts of sabotage against shipping casks. (Note: The shield walls of shipping casks for spent nuclear fuel and high-level radioactive waste are similar to the massive layered construction used in armored vehicles such as tanks.) These kinds of devices were demonstrated by the study to be capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment.

The truck cask design selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art design recently certified by the Nuclear Regulatory Commission to ship four pressurized-water reactor nuclear fuel assemblies (NRC 1998, all). The rail cask design used was based on the conceptual design developed by DOE for the dual-purpose canister system. This design is representative of large rail casks that could be certified for shipping spent nuclear fuel and high-level radioactive waste.

DOE used the RISKIND code (Yuan et al. 1995, all) to evaluate the radiological health and safety impacts of the estimated releases of radioactive materials. The analysis used assumptions about the concentrations of radioisotopes in spent nuclear fuel, population densities, and atmospheric conditions (weather) used to evaluate the maximum reasonably foreseeable accidents.

Because it is not possible to forecast the location or the environmental conditions that might exist for acts of sabotage, the analysis determined impacts for urbanized areas (see Appendix J, Section J.1.4.2.1) under neutral (average) weather conditions.

For legal-weight truck shipments, the analysis estimated that a sabotage event occurring in an urbanized area could result in a population dose of 31,000 person-rem. This dose would cause an estimated 15 fatal cancers among the population of exposed individuals. A maximally exposed individual 150 meters (490 feet) from the event would receive a dose of 67 rem, which would increase the risk of a fatal cancer by about 7 percent.

The impacts estimated for an act of sabotage involving a rail shipment would be less than those estimated for a legal-weight truck shipment. The smaller impact for the rail shipment would be because less of the radionuclides would be released from a rail transportation cask than from a legal-weight truck transportation cask. For rail shipments, the analysis estimated that a sabotage event in an urbanized area could result in a population dose of 4,900 person-rem. This dose would be likely to cause 2.4 fatal cancers among the population of exposed individuals. A maximally exposed individual 140 meters (460 feet) from the event would receive a dose of 11 rem, which would increase the risk of a fatal cancer by about 0.6 percent.

The estimated impacts would be greater for an act of sabotage against a legal-weight truck shipment than against a rail shipment, even though the amount of spent nuclear fuel in a rail cask would be as much as six times that in a truck cask. The greater impacts would be a result of the estimate that an event involving the smaller truck cask would release greater quantities of radioactive materials (Luna, Neuhauser, Vigil 1999, all).

6.2.5 ENVIRONMENTAL JUSTICE

Shipments of spent nuclear fuel and high-level radioactive waste would use the Nation's existing railroads and highways. DOE expects that the impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; utilities, energy, and materials; and waste management would be small. In addition, as described in the preceding sections, incident-free transportation and the risks from transportation accidents (the maximum reasonably foreseeable accident scenario would have 1.9 chances in 10 million of occurring per year) would not present a large health or safety risk to the population as a whole, or to workers or individuals along national transportation routes. The low effect on the population as a whole also would be likely for any segment of the population, including minorities, low-income groups, and members of Native American tribes.

A previous DOE analysis of the potential for environmental justice concerns from the transportation of DOE spent nuclear fuel to the Idaho National Engineering and Environmental Laboratory (DOE 1995a, Volume 1, pages L-2 and L-36) also concluded that impacts to minority and low-income populations and to populations of Native Americans in Idaho would not be disproportionately high and adverse. As part of that analysis, DOE consulted with the Shoshone Bannock Tribe to analyze impacts to tribal members because the shipments in question would cross the Fort Hall Reservation. The analysis (DOE 1995a, Volume 3, Part A, page 3-32) concluded that risks to the health and safety of the potentially affected tribal population in Idaho from incident-free transportation and from accidents would be very low.

Based on the analysis of incident-free transportation and transportation accidents in this EIS and the results of a transportation analysis conducted by DOE in a previous programmatic EIS, and the fact that DOE has identified no subsection of the population that would be disproportionately affected by transportation related to the Proposed Action, DOE has concluded that no disproportionately high and adverse impacts would be likely on minority or low-income populations from the national transportation of spent nuclear fuel and

high-level radioactive waste to Yucca Mountain. Chapter 4, Section 4.1.13.4, contains a discussion of a Native American perspective on the Proposed Action.

6.3 Nevada Transportation

The analysis of impacts from national transportation includes those from transportation activities in the State of Nevada. This section discusses Nevada transportation impacts separately. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, environmental and engineering analysis, state and local government consultation, and National Environmental Policy Act reviews.

This section describes potential impacts of three transportation scenarios and their respective implementing alternatives. The three transportation scenarios are (1) mostly legal-weight truck (corresponding to that portion of the national impacts that would occur in Nevada), (2) mostly rail, and (3) mostly heavy-haul truck.

The mostly legal-weight truck scenario does not include implementing alternatives. Under this scenario, highway shipments would be restricted to specific routes that satisfy the regulations of the U.S. Department of Transportation (49 CFR Part 397). Because the State of Nevada has not designated alternative preferred routes, only one combination of routes for legal-weight truck shipments would satisfy U.S. Department of Transportation routing regulations (I-15 to U.S. Highway 95 to Yucca Mountain). This scenario assumes that over 24 years approximately 300 shipments of naval spent nuclear fuel would arrive in Nevada by rail from the Idaho National Engineering and Environmental Laboratory and that heavy-haul trucks would transport them to the repository from a railhead.

The mostly rail scenario has five implementing alternatives, each of which includes a corridor alignment for a branch rail line in Nevada. Each implementing alternative includes the construction and operation of a rail line. These alternatives would include about 2,600 legal-weight truck shipments (about 110 per year) from 9 commercial sites that do not have the capability to load rail casks.

The mostly heavy-haul truck scenario has implementing alternatives for five different routes on existing Nevada highways. The highways would have to be upgraded to enable heavy-haul trucks routinely to transport rail casks containing spent nuclear fuel and high-level radioactive waste from an intermodal transfer station to the repository. Each heavy-haul truck alternative includes the construction and operation of an intermodal transfer station that DOE would use to transfer loaded rail casks from railcars to heavy-haul trucks and empty rail casks from the trucks to railcars. The analysis considered three potential intermodal transfer station locations. Each heavy-haul implementing alternative would also include 2,600 legal-weight truck shipments over 24 years from the 9 commercial sites that cannot load rail casks.

Chapter 2, Section 2.1.3.3, contains detailed descriptions of the transportation scenarios and implementing alternatives in Nevada. Sections 6.3.1 through 6.3.3 discuss potential impacts for the three Nevada transportation scenarios. Section 6.3.1 discusses potential environmental impacts that could occur in Nevada for the national mostly legal-weight truck scenario. Section 6.3.2 discusses potential environmental impacts for each of the five Nevada rail transportation implementing alternatives, including those from the construction and operation of a branch rail line, and the impacts of 2,600 legal-

weight truck shipments over 24 years. Section 6.3.3 discusses potential impacts of each of the five Nevada heavy-haul truck transportation implementing alternatives, including upgrading Nevada highways, the associated activities of constructing and operating an intermodal transfer station, and the impacts of 2,600 legal-weight truck shipments over the 24 years of operations. Appendix J presents an analysis of impacts of transporting people and materials that would be necessary to implement the Proposed Action. Appendix J also discusses the methods used to analyze impacts for the 12 resource areas.

The EIS analysis evaluated potential impacts that would occur in Nevada from the construction and operation of a branch rail line or from upgrades to highways and construction and operation of an intermodal transfer station for the following environmental resource areas: land use and ownership; air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise; aesthetics; utilities, energy, and materials; waste management; and environmental justice. The following paragraphs describe the methods used to evaluate potential impacts to these resource areas for each of the three Nevada transportation scenarios —legal-weight truck, rail, and heavy-haul truck— and their applicable implementing alternatives.

Land Use and Ownership

DOE determined that information useful for an evaluation of land-use and ownership impacts should identify the current ownership of the land that its activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts was defined as land areas that would be disturbed or whose ownership or use would change as a result of the construction and use of a branch rail line, intermodal transfer station, midroute stopover for heavy-haul trucks, and an alternative truck route near Beatty, Nevada.

Air Quality

The evaluation of impacts to air quality considered potential emissions of criteria pollutants [nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulates with aerodynamic diameters of less than 10 and 2.5 micrometers (PM_{10} and $PM_{2.5}$)] and ozone, the percentage of applicable standards and limits, and the potential for releases of these pollutants in the Las Vegas Valley. The region of influence for the air quality analysis included (1) the Las Vegas Valley for implementing alternatives that could contribute to the levels of carbon monoxide and PM_{10}, which are already in nonattainment of standards (FHWA 1996, pages 3-53 and 3-54), during the construction and operation of a branch rail line or highway for heavy-haul trucks, and (2) the atmosphere in the vicinity of the sources of criteria pollutants that transportation-related construction and operation activities would emit.

Hydrology

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding or dredging and filling actions to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction activities, areas that would be affected by permanent changes in flow, and areas downstream of construction.

The analysis addressed the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, availability for use for construction and, if available, potential that such use would affect other users. The region of influence for this analysis included groundwater reservoirs.

Biological Resources and Soils

The evaluation of impacts to biological resources considered the potential for conflicts with areas of critical environmental concern; special status species (plants and animals), including their habitats; and jurisdictional waters of the United States, including wetlands and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of big game animals. The region of influence for this analysis included the following:

- Habitat, including jurisdictional waters of the United States, including wetlands and riparian areas
- Migratory ranges of big game animals that could be affected by the presence of a branch rail line

The analysis assessed soil impacts to determine the potential to increase erosion rates by water or wind. The region of influence for the analysis of soil impacts included areas where construction would take place and downwind or downgradient areas that would be affected by eroded soil.

Cultural Resources

The evaluation of impacts on cultural resources considered the potential for disrupting, or modifying the character of, archaeological or historic sites, artifacts, and other cultural resources.

The region of influence for the analysis included the lands in the 400-meter (1,300-foot)-wide rail corridors, lands near highways that would be upgraded for heavy-haul truck use, and sites where an intermodal transfer station could be constructed and operated.

Occupational and Public Health and Safety

The analysis of impacts to occupational and public health and safety from transportation-related activities in Nevada used the same methods, assumptions, attributes, and regions of influence used for the analysis of impacts of national transportation of spent nuclear fuel and high-level radioactive waste. However, it used the rail and highway accident rates reported for the State of Nevada (Saricks and Tompkins 1999, Table 4).

In addition, the analysis included potential impacts from industrial hazards to Nevada workers from constructing and operating a branch rail line, upgrading highways for use by heavy-haul trucks, and constructing and operating an intermodal transfer station. The region of influence for the analysis included branch rail line and highway construction work sites and highways that workers and other construction-related vehicle traffic would use.

The analysis considered potential radiological impacts from intermodal transfer station operations.

Socioeconomics

The analysis of socioeconomic impacts considered changes in employment, personal income, population, Gross Regional Product, and state and local government expenditures. The region of influence for the analysis included Clark, Lincoln, and Nye Counties. The other Nevada counties were included collectively.

Noise

Nevada does not have a noise code, so the analysis used daytime and nighttime noise standards adopted by most states for residential and commercial areas to evaluate the impacts of noise from construction and operation activities. The region of influence considered in the analysis included inhabited commercial and residential areas where noise from construction and noise from trains or trucks would have the potential to exceed 45 dBA.

Aesthetics

The analysis of potential impacts on aesthetic resources considered Bureau of Land Management ratings for land areas (BLM 1986, all). The regions of influence used in the analysis included the landscapes along the potential rail corridors and highway routes and near possible locations of intermodal transfer stations with aesthetic quality that construction and operations could affect.

The analysis of impacts was based on visual sensitivity ratings of viewsheds in Nevada and the Bureau of Land Management Visual Resource Management System objectives. It established ratings for scenery based on the number and types of users, public interest in the area, and adjacent land uses. The ratings are based on the scenic quality classes in the Bureau of Land Management Visual Resource Management System (BLM 1986, all).

Utilities, Energy, and Materials

The attributes used to assess impacts to utilities, energy, and materials included the requirements for electric power, fossil fuel for construction, and key consumable construction materials. The analysis compared needs to available capacity. The region of influence included the local, regional, and national supply infrastructure that would have to satisfy the needs.

Waste Management

Evaluations of impacts of waste management considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that would be generated. The region of influence included construction areas and camps and facilities that would support transportation operations such as locomotive and railcar maintenance facilities.

Environmental Justice

The analysis of environmental justice for the Nevada transportation scenarios is identical to that described for national transportation in Section 6.2.5. Section 6.3.4 describes the results of that analysis for the Nevada transportation scenarios.

6.3.1 IMPACTS OF THE NEVADA MOSTLY LEGAL-WEIGHT TRUCK TRANSPORTATION SCENARIO

Legal-weight truck shipments in Nevada of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use existing highways and would be a very small fraction of the total traffic [less than 1.2 million kilometers (750 thousand miles) per year for legal-weight truck shipments in Nevada in comparison to an estimated 1.2 billion kilometers (750 million miles) per year of commercial vehicle traffic on I-15 and U.S. Highway 95 in southern Nevada]. As a consequence, impacts to land use; hydrology; air quality; biological resources; cultural resources; socioeconomics; noise; aesthetics; utilities, energy, and materials; and waste management would not be large. Nonetheless, because of concern about additional threats to populations of desert tortoises, this section addresses the potential for impacts to this threatened species. This section focuses on impacts to occupational and public health and safety in Nevada. Section 6.3.4 contains a consolidated discussion of the potential for transportation activities to cause environmental justice impacts.

6.3.1.1 Impacts to Biological Resources

Legal-weight truck shipments in Nevada to a Yucca Mountain Repository would involve travel over highways that cross desert tortoise habitat, but none of the routes would cross habitat that the Fish and Wildlife Service has designated as critical for the recovery of this threatened species (50 CFR 17.95). Over the course of 24 years of operations under the Proposed Action and 49,500 shipments, vehicles probably would kill individual desert tortoises. However, under this scenario legal-weight trucks would

contribute only about 1 percent to the daily traffic of vehicles to and from the repository site and only about 0.15 percent of all commercial truck traffic along I-15 and U.S. 95 in southern Nevada. Thus, any desert tortoises killed by trucks transporting spent nuclear fuel or high-level radioactive waste probably would be only a small fraction of all desert tortoises killed on highways. Loss of individual desert tortoises due to legal-weight truck shipments would not be a large threat to the conservation of this species.

6.3.1.2 Impacts to Occupational and Public Health and Safety

6.3.1.2.1 *Impacts from Incident-Free Transportation*

This section addresses radiological impacts to populations and maximally exposed individuals in Nevada from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. It includes potential impacts from exposure to vehicle emissions in Nevada.

Incident-Free Radiological Impacts to Populations. Table 6-13 lists the incident-free population dose and radiological impacts for the Nevada mostly legal-weight truck scenario. The impacts include those from the shipment of naval spent nuclear fuel by rail in Nevada, intermodal transfer activities, and subsequent heavy-haul truck transportation to the proposed repository. The analysis included the radiological impacts of intermodal transfer operations for naval spent nuclear fuel shipments. Occupational impacts would include estimated radiological exposures to security escorts for legal-weight truck, rail, and heavy-haul truck shipments. The estimated radiological impacts would be 0.6 latent cancer fatality for workers and 1.4 latent cancer fatalities for members of the public over the 24 years of operation.

Table 6-13. Population doses and radiological health impacts from incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	1,600	32	1,600
Estimated LCFs[d]	0.62	0.01	0.63
Public			
Collective dose (person-rem)	2,800	26	2,800
Estimated LCFs	1.4	0.01	1.4

a. Impacts are totals for shipments over 24 years.
b. Includes impacts at intermodal transfer stations.
c. Totals might differ from sums of values due to rounding.
d. LCF = latent cancer fatality.

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-14 lists estimates of dose and radiological impacts for maximally exposed individuals for the Nevada legal-weight truck scenario from 24 years of shipment activity. The analysis used the assumptions presented in Section 6.2.1 and Appendix J.

The analysis assumed the annual dose to state inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste would be limited to 2 rem.

The analysis estimated that a maximally exposed individual at a service station would receive 2.4 person-rem over 24 years under the legal-weight truck scenario. This estimate conservatively assumed the person would be exposed to 430 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,100 legal-weight truck shipments per year, about 430 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in

Table 6-14. Estimated doses and radiological health impacts to maximally exposed individuals during incident-free transportation for Nevada mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00006
Public		
Resident along route	0.005	0.000003
Person in traffic jam	0.04[d]	0.00002
Person at service station	2.4[e]	0.0001
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Impacts are totals over 24 years.
c. Assumes 2-rem-per-year dose limit.
d. Single occurrence.
e. Assumes the person works at the service station for all 24 years of repository operations.

1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 430.

Impacts from Vehicle Emissions. There is potential for human health impacts to people in Nevada who would be exposed to pollutants emitted from vehicles transporting spent nuclear fuel and high-level radioactive waste, including escort vehicles. Table 6-15 lists the estimated number of vehicle emission-related fatalities from legal-weight trucks, heavy-haul trucks, escort vehicles, and rail locomotives under the mostly legal-weight truck scenario. Trucks would be the major contributors. No vehicle emission-related fatality (0.0055) would be likely.

Table 6-15. Population health impacts from vehicle emissions during incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Total
Vehicle emission-related fatalities	0.005	0.0005	0.0055

a. Impacts are totals for shipments over 24 years.
b. Includes heavy-haul truck shipments in Nevada.

6.3.1.2.2 *Impacts from Accidents – Nevada Legal-Weight Truck Scenario*

This section discusses radiological impacts to populations and maximally exposed individuals in Nevada and the potential number of traffic accident fatalities from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. The analysis of accident impacts under this scenario includes impacts from accidents that would occur during the transportation of naval spent nuclear fuel by rail in Nevada to an intermodal transfer station and by heavy-haul truck to the repository. Section 6.3.3 discusses impacts to workers from industrial hazards during the operation of an intermodal transfer station for shipments of naval spent nuclear fuel.

Radiological Impacts from Accidents. The calculated collective radiological accident dose risk would be 0.5 person-rem for the population in Nevada within 80 kilometers (50 miles) along the routes under the mostly legal-weight truck transportation scenario. This is the total dose risk for 24 years of shipment operations (2010 to 2033), and would result in 0.0002 latent cancer fatality in the exposed population. The radiological risk from accidents would include impacts from approximately 49,500 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments. The accident risk for legal-weight truck

shipments would account for essentially all of the population dose and radiological impacts. Because DOE would not build a branch rail line to the repository under this scenario, the accident risk for rail shipments of naval spent nuclear fuel includes risks from accidents that could occur during intermodal transfers from railcars to heavy-haul trucks and during heavy-haul transportation in Nevada. Section 6.3.3 provides additional information on heavy-haul truck implementing alternatives for transporting rail casks in Nevada.

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario presented in Section 6.2.4.2.1.

Impacts from Traffic Accidents. In Nevada, less than 1 (0.5) fatality from traffic accidents would be likely during the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck transportation scenario. This estimate includes traffic fatalities involving escort vehicles.

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS IN NEVADA

Maximum reasonably foreseeable accident scenarios analyzed for transportation in Nevada were the same as maximum reasonably foreseeable accident scenarios analyzed in Section 6.2.4.2 for national transportation. That is, the EIS analysis assumed that an accident determined to be reasonably foreseeable for national transportation would occur in Nevada. Because the distances traveled in Nevada would be much less than the total national travel to deliver spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, the likelihoods of these accident scenarios occurring in the State would be less than those for the rest of the Nation. The likelihoods of two of these accident scenarios occurring in national travel are reported in Section 6.2.4.2.

6.3.2 IMPACTS OF NEVADA RAIL TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five rail transportation implementing alternatives, each of which would use a newly constructed branch rail line in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. The branch line would transport railcars carrying large shipping casks from a mainline railroad to the repository (loaded) and back (empty). DOE has identified five 0.4-kilometer (0.25-mile)-wide corridors of land—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified for the possible construction and operation of the branch line (Figure 6-10). Chapter 2, Section 2.1.3.3.2 describes the corridors. Chapter 3 discusses their affected environments.

Appendix J contains additional information on the characteristics of possible alignment variations of each corridor. Figure 6-10 shows these variations. Section 6.3.2.1 discusses impacts that would be common among the five possible corridors, and Section 6.3.2.2 discusses impacts that would be unique for each corridor.

DOE identified the five rail corridors through a process of screening the potential rail alignments it had studied in past years.

- The *Feasibility Study for Transportation Facilities to Nevada Test Site* study (Holmes & Narver 1962, all) determined the technical and economic feasibility of constructing and operating a railroad from Las Vegas to Mercury.

- The *Preliminary Rail Access Study* (Tappen and Andrews 1990, all) identified 13 and evaluated 10 rail corridor alignment options. This study recommended the Carlin, Caliente, and Jean corridors for detailed evaluation.

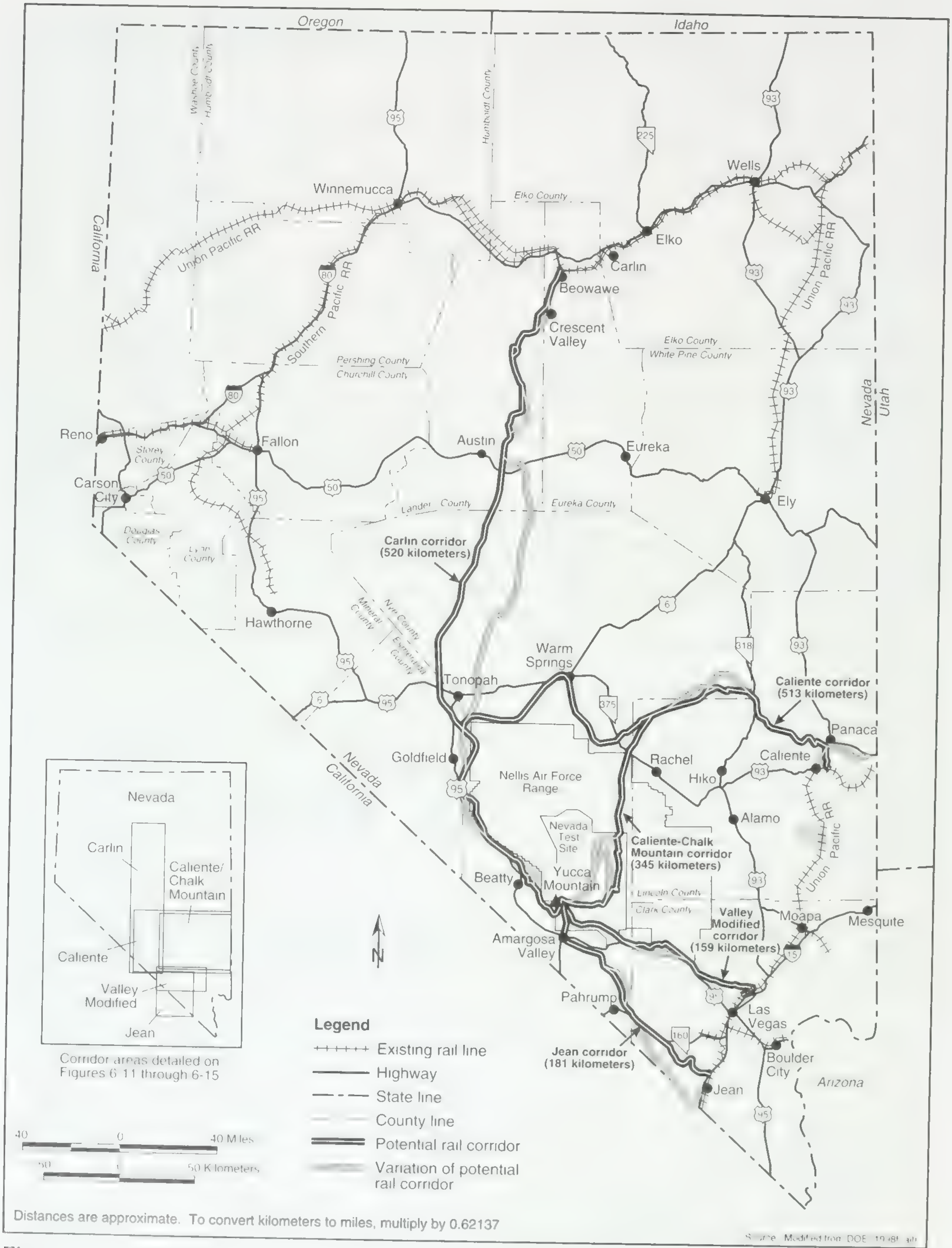


Figure 6-10. Potential Nevada rail routes to Yucca Mountain.

- *The Nevada Railroad System: Physical, Operational, and Accident Characteristics* (DOE 1991b, all) described the operational and physical characteristics of the current Nevada railroad system.

- The *High Speed Surface Transportation Between Las Vegas and the Nevada Test Site (NTS)* report (Raytheon 1994, all) explored the rationale for a potential high-speed rail corridor between Las Vegas and the Nevada Test Site to accommodate personnel.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (TRW 1995a, all), reevaluated 13 previously identified rail routes and evaluated a new route called the Valley Modified route. This study recommended four rail routes for detailed evaluation—the Caliente, Carlin, Jean, and Valley Modified routes.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 2* (TRW 1996, all), further refined the analyses of potential rail corridor alignments in Study 1.

Public comments submitted to DOE during hearings on the scope of this EIS resulted in the addition of a fifth potential rail corridor—Caliente-Chalk Mountain.

The analysis of impacts for the five Nevada rail transportation implementing alternatives assumed the mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from nine commercial sites that do not have the capability to handle or load a large rail cask. About 2,600 legal-weight truck shipments over 24 years would enter Nevada and travel to the repository. These shipments would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those described for the mostly legal-weight truck scenario (Section 6.3.1).

The analysis evaluated impacts to land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise; aesthetics; utilities, energy, and materials; and waste management. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.1 Impacts Common to Nevada Branch Rail Line Implementing Alternatives

This section discusses impacts for the analysis areas listed above that would be common to all five branch rail line implementing alternatives. DOE evaluated these impacts as described in Section 6.3. The construction of the branch rail line would last about 2.5 years under each implementing alternative. Shipping operations in the rail corridor would begin at a mainline switching station where railcars carrying casks of spent nuclear fuel and high-level radioactive waste would switch from the mainline to the branch line for transport to the repository, and railcars carrying empty casks from the repository would switch to the mainline for transport back to the commercial and DOE sites. These shipments would continue for 24 years. Section 6.3.2.2 discusses impacts specific to each rail implementing alternative.

Land Use and Ownership

In calculating the amount of land affected by a rail corridor, the analysis assumed a corridor width of 400 meters (1,300 feet). The purpose of the 400-meter width was to provide sufficient space for final alignment to route the rail line around sensitive land features. Actual construction and operation in the corridor would mostly require less than about 60 meters (200 feet) of the 400-meter width. Thus, about 15 percent of the land in the corridor would be disturbed by construction at most. The analysis also assumed that about 2 square kilometers (500 acres) of land outside the corridor would be disturbed during

the construction of a branch rail line for construction roads and camps and other construction-related activities.

In relation to rail line operations, train and track inspection and maintenance activities would be confined to the areas that construction activities had disturbed, so no additional disturbance would occur.

The rail corridors have possible alignment variations with slightly different land ownerships and projected disturbances. These possible variations in the corridor alignments would make little difference in land-use impacts, so this section does not discuss them in detail.

Each corridor has areas the public uses and areas available for sale and transfer. As a consequence, the rail line could result in limited access to areas currently in use by the public. Similarly, because of the corridor interface with grazing lands and wildlife areas, the rail line could create a barrier to livestock movement. Impacts to wildlife are discussed later in this section.

The analysis indicates no conflicts with commercial use and no identified conflicts with scientific studies for any of the proposed corridors. At present, the public land in each corridor, with the exception of portions of the Caliente-Chalk Mountain corridor, is open to mining and offroad vehicle use.

The potential land-use conflicts of greatest concern are those that would present long-term conflicts with other uses. One conflict in this category concerns the Caliente-Chalk Mountain corridor, which, according to the Air Force, would conflict with the national security mission on the Nellis Air Force Range (Henderson 1997, all). These lands were withdrawn for use as a high-hazard military weapons training and testing area; Air Force restrictions limit transportation options across these lands.

Air Quality

Construction. The construction of a branch rail line would comply with all applicable air quality regulations and associated requirements in the construction permits. Construction activities would increase pollutant concentrations in the areas near the rail corridor. Fuel use by construction equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter with diameters of 10 micrometers or less (PM_{10}) and 2.5 micrometers or less ($PM_{2.5}$). Construction activities would also emit PM_{10} in the form of fugitive dust from excavation and truck traffic. The emissions would be temporary and would cover a very large area as construction moved along the length of the corridor.

Operations. Fuel use by diesel train engines would emit carbon monoxide, nitrogen dioxide, PM_{10}, and $PM_{2.5}$. Based on the Federal standards for locomotives (EPA 1997a, all), there would be no significant emissions of sulfur dioxide.

No air quality impacts would be unique to the branch rail line implementing alternatives with the exception of the Valley Modified corridor, as described in Section 6.3.2.2.5.

Hydrology

This section describes impacts to surface water and groundwater.

Surface Water

Construction. Construction-related impacts could involve the possible release and spread of contaminants by precipitation or intermittent runoff events or, for corridors near surface water, possible release to the surface water, the alteration of natural drainage patterns or runoff rates that could affect downgradient resources, and the need for dredging or filling of perennial or ephemeral streams.

Construction-related materials that could cause contamination would consist of petroleum products (fuels and lubricants) and coolants (antifreeze) necessary to support equipment operations. In addition, remote work camps would include some bulk storage of these materials, and supply trucks would routinely bring new materials and remove used materials (lubricants and coolants) from the construction sites. These activities would present some potential for spills and releases. Regulatory requirements on reporting and remediating spills and properly disposing of or recycling used materials would result in a low probability of spills. If a spill occurred, the potential for contamination to enter flowing surface water would present the greatest risk of a large migration of a contaminant before remediation took place. If there was no routinely flowing surface water (most areas along the corridors), released material would not travel far or affect critical resources before remediation occurred. During construction activities, water spraying would control dust and achieve soil compaction criteria, but water would not be used in quantities large enough to support surface-water flow and possible contaminant transport for any distance.

During construction, a contractor would move large amounts of soil and rock to develop the track platform (subgrade) and the access road. These construction activities could block storm drainage channels temporarily. However, the contractor would use standard engineering design and best management practices to place culverts, as appropriate, to move runoff water from one side of the track or road to the other. These culverts or other means of runoff control would be put in place early in the construction effort, because standing water in the work area would generally hinder progress.

Depending on site-specific conditions, construction could include regrading such that a number of minor drainage channels would collect in a single culvert, resulting in water flowing from a single location on the downstream side rather than across a broader area. This would cause some localized changes in drainage patterns but probably would occur only in areas where natural drainage channels are small.

Operations. The use of a completed branch rail line would have little impact on surface waters beyond the permanent drainage alterations from construction. The road and rail beds probably would have runoff rates different from those of the natural terrain but, given the relatively small size of the potentially affected areas in a single drainage system, there would be little impact on overall runoff quantities.

There would be no surface-water impacts unique to any of the branch rail line implementing alternatives with the exception of their relative proximity to surface-water resources.

Appendix L contains a floodplain/wetlands assessment that examines the effects of branch rail line construction, operation, and maintenance on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. There are no delineated wetlands at Yucca Mountain.

If DOE selected rail to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would also select one of five routes (Figure 6-10). DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternative. The assessment in Appendix L presents a comparison of what is known about the floodplains, springs, and riparian areas and at the three alternative intermodal transfer station sites and along their associated heavy-haul routes. In general, wetlands have not been delineated along the alternative intermodal transfer station sites.

Groundwater

Construction. Potential groundwater impacts from rail line construction could include changes to infiltration rates, new sources of contamination that could migrate to groundwater, and depletion of groundwater resources resulting from increased demand. However, the potential for impacts would be spread over a large geographic area, so the probability would be low for a resource in a single area to receive adverse impacts. The above discussion of impacts to surface water identifies potential

contaminants that branch rail line construction could release. These contaminants would be the same for groundwater.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this situation would be short-lived as the access road and railbed materials became compacted and less porous. In either case, localized changes in infiltration probably would cause no noticeable change in the amount of recharge in the area.

The analysis assumed that a number of wells would be required to support construction and that they would be installed along the rail corridor. It also assumed a 1-year period for construction activities in the vicinity of each well. Water withdrawal from these wells would not contribute to the depletion of a particular groundwater basin for two reasons: (1) the demand would be relatively short-term because it would stop when construction was complete, and (2) annual demands would be limited to a fraction of the perennial yields of the aquifers that would supply the water (see Table 3-35). In addition, the Nevada State Engineer would approve water production from any well installed to support rail corridor construction. To grant approval, the State Engineer would have to determine that the short-term demand would not cause adverse impacts for other uses and users of the groundwater resource.

For the case in which water was obtained from a source other than a newly installed well and brought to the construction site by truck, water would be obtained from appropriated sources. That is, the water would be from allocations that the Nevada State Engineer had previously determined did not adversely affect groundwater resources.

Impacts on groundwater would differ among the implementing alternatives. These impacts, which Section 6.3.2.2 describes for the implementing alternatives, would include the projected water needs to support the construction of each candidate rail corridor and the estimated number of wells DOE would install along each corridor to meet that need.

Operations. The use of a completed railway corridor would have little impact on groundwater resources. There would be no continued need for water along the corridor, and possible changes to recharge, if any, would be the same as those at the completion of construction.

Biological Resources and Soils

Construction. Construction activities would generally disturb no more than about 15 percent of the land inside a 400-meter (1,300-foot)-wide corridor. Vegetation would be cleared in an area generally less than 60 meters (200 feet) wide in the corridor to enable the construction of the railroad and a parallel access road. Vegetation would also be cleared from borrow areas and covered in disposal areas for excavated materials. Land for construction camps and in small areas where wells would be drilled would also be cleared of vegetation.

Impacts to biological resources from the construction of a branch rail line would occur due to a loss of habitat for some terrestrial species. Individuals of some species would be displaced or killed by construction activities. After the selection of a rail corridor, DOE would perform preconstruction surveys of potentially disturbed areas to identify and locate special status species that would need to be protected during construction.

Construction could affect the following biological resources:

- *Game and Game Habitat.* Each candidate rail corridor would cross or be near [within 5 kilometers (3 miles)] several areas the Bureau of Land Management and the Nevada Division of Wildlife have designated as game habitat (TRW 1999k, pages 3-23 to 3-32). Construction activities in these areas

would result in a loss of some habitat. Each rail corridor has the potential to disrupt movement patterns of game animals. The design of fences, if built along the rail corridor, would accommodate the movement of these animals. Large animals including game species (elk, bighorn sheep, mule deer, etc.), wild horses, and burros probably would avoid contact with humans at construction locations and would temporarily move to other areas during construction. Numerous special status species occur along each of the proposed branch rail lines. Construction of a branch rail line could lead to habitat loss and fragmentation for the special status species, as well as to mortality of individuals.

- *Special Status Species.* The construction of a branch rail line in any of the five rail corridors would involve the loss of varying amounts [1.4 to 6.3 square kilometers (350 to 1,600 acres)] of desert tortoise habitat. None of the corridors cross areas designated by the Fish and Wildlife Service as critical desert tortoise habitat (50 CFR 17.95). The abundance of tortoises varies from very low to medium along the proposed corridors (Karl 1980, pages 75 to 87; Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411), but some desert tortoise deaths could occur during land-clearing operations. Loss of habitat and mortality of individuals of other special status species along specific routes could also occur.

- *Wetlands and Riparian Areas.* Each corridor could affect a number of wetlands, springs, and riparian areas (TRW 1999k, pages 3-23 to 3-32). These areas are generally important for biological resources and typically have high biodiversity. Potential impacts to these areas include destruction, alteration, or fragmentation of habitat; increased siltation in streams during construction; changes in stream flow; and loss of biodiversity.

All of the candidate rail corridors cross perennial or ephemeral streams that may be classified as jurisdictional waters of the United States. Section 404 of the Clean Water Act regulates discharges of dredged or fill material into such waters. After the selection of a rail corridor, DOE would identify any jurisdictional waters of the United States that the construction of a rail line would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters; and, as applicable, obtain an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be small.

The general design criteria for a branch rail line would include a requirement that a 100-year flood would not inundate the rails at channels fed by sizable drainage areas. During the operation and monitoring phase of the repository, conditions more intense than those that would generate a 100-year storm could occur in the area. Such conditions, depending on their intensity, could wash out access roads and possibly even the rail line. Although DOE would have to repair these structures, there is no reason to believe that such an occurrence would unduly affect area resources. If necessary, a permit would be obtained from the U.S. Army Corps of Engineers for discharge of dredge and fill material to repair the rail line. There would be no contamination that floodwaters could spread and, with the exception of areas of steep terrain, debris would not travel far. The operation of a branch rail line would stop during conditions that could lead to the flooding of track areas and would not resume until DOE had made necessary repairs.

Soil impacts from rail line construction would be primarily the direct impacts of land disturbance in the selected corridor. The amount of land disturbance, both inside and outside the corridor, would vary by corridor. The disturbed areas probably would be subject to an increase in erosion potential for at least some of the construction phase. DOE would use dust suppression measures to reduce this potential. As construction proceeded, the railbed would be covered with ballast rock, which would virtually halt erosion from that area, and the access roads would be compacted, which would reduce erosion. As

construction ended, disturbed areas (other than the railbed and access roads) would slowly recover. Other permanent erosion control systems would be installed as appropriate. Introduction of contaminants into the soil is also a potential concern. Proper control of hazardous materials during construction and prompt response to spills or releases would, however, reduce this concern. Impacts to soils would be limited to these areas disturbed and would be transitory and small.

Operations. Impacts to biological resources from shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository along any of the five rail corridors would include periodic disturbances of wildlife from trains going by and from personnel servicing the corridor. Trains probably would kill individuals of some species.

Rail operations would not lead to additional habitat losses, although maintenance activities would prevent habitat recovery in the narrow band occupied by the rail line and access road. Operations could affect individuals of some species, but losses would be unlikely to affect the regional population of any species. Passing trains could disrupt wildlife but such effects would be transitory.

The use of a completed railway would not be likely to have an impact on soils. The rail track and roadbed would be maintained throughout the operations phase, including repairs of erosion damage to the access road and railbed.

Cultural Resources

Construction. Table 3-36 lists the cultural resource information currently available in each corridor that branch rail line construction could affect. Direct impacts to these cultural resources (such as disturbing the sites or crushing artifacts) could occur from a variety of construction-related activities, including building the rail line and the right-of-way. In addition, rail line construction activities would include borrow areas, areas for the disposal of excavated material, construction camps, and access roads that would be outside the defined right-of-way. Because archaeological sites sometimes include buried components, ground-disturbing actions could uncover previously unidentified cultural materials. If cultural resources were encountered, a qualified archaeologist would participate in directing activities to ensure that the resources would be properly protected or the impact mitigated. DOE would use procedures to avoid or reduce direct impacts to cultural resources in construction areas where surface-disturbing activities would occur (see Chapter 9).

Indirect impacts, such as non-project-related disturbances of archaeological sites by purposeful or accidental actions of project employees, could occur from construction activities as a result of increased access and increased numbers of workers near cultural resource sites. These factors would increase the probability for either intentional or inadvertent indirect impacts to cultural resources.

The EIS analysis identified no potential impacts to Native American resources along the corridors. However, systematic studies have not been completed to identify sites, resources, or areas that might hold traditional value for Native American peoples or communities. The corridors would not affect identified cultural resources on reservations because they would not pass through reservations. However, AIWS (1999, page 4-6) states that all wetlands are important cultural resources. If sites or resources important to Native Americans were discovered in the future, either in or near an identified right-of-way, adverse effects could occur through direct means, such as construction activities, or indirectly through visual or auditory impacts.

Operations. No additional direct or indirect impacts would be likely at archaeological and historic sites from the operation of the rail line.

At present, no specific impacts to Native American resources, traditional cultural properties, or other cultural values from rail operations have been identified. In general, the Consolidated Group of Tribes and Organizations has noted that the rail corridors pass through the traditional holy lands of the Southern Paiute, and that many of the corridors correspond, or are adjacent, to ancient pathways and trail systems. Native Americans believe that operation of a branch rail line that transports spent nuclear fuel and high-level radioactive waste would constitute adverse impacts to traditional values and have identified it as a very important concern. They have requested that the tribes and groups that make up the Consolidated Group of Tribes and Organizations be consulted regularly on transportation issues and scheduling to ensure impacts would be small.

Other than those described above, there would be no cultural impacts unique to any of the branch rail line implementing alternatives.

Occupational and Public Health and Safety

Incident-Free Transportation. Incident-free impacts of rail transportation in Nevada would be unique for each of the five Nevada rail transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.2.2. That section also lists the incident-free impacts that would occur in Nevada from 2,600 legal-weight truck shipments, although they would be common among the rail implementing alternatives.

Accidents. Accident risks and maximum reasonably foreseeable accidents for rail shipments of spent nuclear fuel and high-level radioactive waste would be common to the Nevada rail transportation implementing alternatives. This section, therefore, discusses these risks.

Table 6-16 lists accident risks for transporting spent nuclear fuel and high-level radioactive waste in Nevada for the five Nevada rail transportation implementing alternatives. The data show that the risks, which are listed for 24 years of operations, would be low for each alternative. These risks include risks associated with transporting 2,600 legal-weight truck shipments made from the commercial sites that could not load rail casks. Small variations in the risk values, principally evident for the Jean branch rail line, are a result of risks that would be associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area. The values that would apply for a Valley Modified or Caliente-Chalk Mountain branch line would be lower because of a shorter corridor (Valley Modified), or a more remote and mid-length corridor (Caliente-Chalk Mountain).

Table 6-16. Estimated health impacts[a] to the public from potential accident scenarios for Nevada rail implementing alternatives.

Risk	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Radiological accident risk					
Dose-risk (person-rem)	0.09	0.10	0.09	0.15	0.09
LCFs[b]	0.00005	0.00005	0.00004	0.00008	0.00004
Traffic fatalities	0.13	0.15	0.11	0.11	0.10

a. Data are reported for 24 years of operations.
b. LCFs = latent cancer fatalities.

Consequences of Maximum Reasonably Foreseeable Accidents. The national transportation analysis evaluated impacts of maximum reasonably foreseeable accidents (see Section 6.2.4.2).

Socioeconomics

There would be no socioeconomic impacts common to all the branch rail line implementing alternatives. Section 6.3.2.2 describes socioeconomic impacts for each implementing alternative.

Noise

Construction. Occupational Health and Safety Administration regulations (29 CFR) establish hearing protection standards for workers. DOE would meet these standards for workers involved in building a branch rail line in any of the five corridors. Estimated noise levels for railroad construction would range from 62 to 74 A-weighted decibels (dBA) within 150 meters (500 feet) of the noise source and from 54 to 67 dBA at 600 meters (2,000 feet) (ICC 1992, page 4-97). Trips to borrow and spoil areas would be another source of noise. Rail line construction would occur primarily during daylight hours, so nighttime noise would not be an issue unless there was a need to use accelerated construction to meet schedule constraints. There is a possibility that the construction of some structures associated with the rail line would occur during hours not in the normal workday, but the frequency and associated noise levels would be unlikely to be great. Because construction would progress along a corridor, construction noise would be transient in nearby communities. Noise levels could approach generally accepted limits for residential and commercial areas, but this would be for a brief time. Because there are no permanent residences, construction noise would not be an issue for activities inside the boundaries of Nellis Air Force Range, the Nevada Test Site, or the land withdrawal area that DOE analyzed for the proposed repository.

Operations. About five rail round trips (10 one-way trips) of spent nuclear fuel, high-level radioactive waste, or other material would occur weekly on the branch rail line during normal operations. To estimate noise impacts, the analysis assumed that trains would travel as fast as 80 kilometers (50 miles) an hour. The equivalent-continuous (average) sound level at 2,000 meters (6,600 feet) from a train consisting of two locomotives and 10 cars traveling at 80 kilometers an hour would be 51 dBA (Hanson, Saurenman, and Towers 1991, pages 1 to 8). The estimated noise level at 200 meters (660 feet) would be 62 dBA (Hanson, Saurenman, and Towers 1991, pages 1 to 8). Humans immediately outside a 400-meter (1,300-foot) corridor and the region of influence boundary would experience infrequent exposure to rail noise. In the more isolated regions, few people would be affected. Trains traveling through communities would normally operate at reduced speed, so their noise levels would decrease.

Noise impacts unique to the branch rail line implementing alternatives, with the exception of the Valley Modified implementing alternative (described in Section 6.3.2.2.5), would be unlikely.

Aesthetics

Construction. The greatest impact on visual resources from the construction of a rail line would be the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, and dust generation. These activities, however, would have a limited duration (about 2.5 years). Construction would progress along the selected corridor from its starting point to the proposed repository. Only a small portion of the overall construction time would be spent in one place; the exception to this would be places where major structures, such as bridges, would be built. In general, an individual construction camp would be active only for part of the 2.5-year construction period; after the completion of construction in an area, the camp would close.

Dust generation would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would not exceed the criteria in the Bureau of Land Management Visual Resource Management guidelines (BLM 1986, all). If the rail line crossed Class II lands, more stringent management requirements would be necessary to retain the existing character of the landscape. The short duration of branch rail line construction activities, combined with the use of best management practices, would mitigate the impacts of activities that could exceed the management requirements for Class II lands. Visual impacts to scenic quality Class C lands on the Nevada Test Site would not occur because of the remoteness and inaccessibility of the location.

Operations. During proposed repository operations, visual impacts would be due to the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the

repository. The passage of 10 trains a week (coming and returning) would have a small impact, temporarily attracting the attention of the casual observer. In addition, the noise generated by the trains would attract attention to them, temporarily increasing their impact on the scenic quality of the landscape. There would be no aesthetic impacts unique to any of the branch rail line implementing alternatives.

Utilities, Energy, and Materials

Construction. Because all five corridors pass through sparsely populated areas with little access to support services, portable generators would provide electricity to support construction activities. The total fossil-fuel consumption in Nevada was about 3.8 billion liters (1 billion gallons) in 1996 (BTS 1999a, Table MF-21). Fuel consumption estimates for construction of heavy-haul routes indicate low impacts compared to the statewide consumption of petroleum fuel.

Steel for rails and concrete, principally for rail ties, bridges, and drainage structures, and rock for ballast would be the primary materials consumed in the construction of a branch rail line. DOE would buy precast concrete railbed ties, culverts, bridge beams, and overpass components from a number of suppliers. Actual onsite pouring of concrete [less than 120,000 metric tons (132,000 tons)] would account for less than 30 percent of the total mass of concrete and would be less than 2 percent of the concrete used in Nevada in 1998 (Sherwood 1998, all). Because DOE would buy precast concrete components from suppliers and because onsite concrete construction would involve a small amount of material for some abutments, the localized impact of concrete use in rail corridor construction would not be great for any of the corridors.

Because sources for rails and railroad ties are well established in the southwest and nationally, none of the quantities of materials required for constructing a rail line in Nevada would create demand or supply impacts in southern Nevada (Zocher 1998, all).

Impacts on utilities, energy, and materials differ among the implementing alternatives, as described in Section 6.3.2.2.

Operations. Impacts to utilities, energy, and materials from the operation of a branch rail line in Nevada would be small. Use of fossil fuel for train operations would be small. Chapter 10 discusses fossil fuel used for rail operations. No impacts would be unique to any of the branch rail line implementing alternatives.

Waste Management

Construction. The construction of a branch rail line would require construction materials such as rail ties and steel; rock ballast; concrete; oils, lubricants, and coolants for heavy machinery; and compressed gasses (hazardous materials) for welding. Construction in any of the five corridors would result in small amounts of wastes that would require disposal. Most would be nonhazardous industrial wastes or construction debris that DOE would dispose of in permitted industrial landfills or in permitted construction debris landfills, respectively. Hazardous waste such as lubricants and solvents would be shipped to a permitted hazardous waste treatment and disposal facility for appropriate disposition. In addition, much of the residual material from rail line construction would be saved for reuse or would be recycled. Excess excavated materials such as soil and rock would be placed in spoil areas that would be included in the amount of disturbed land. A commercial vendor would provide portable restroom facilities and manage the sanitary sewage. This waste would be handled such that there would be no adverse impacts from construction.

Operations. The use of a rail line in any of the five corridors would result in wastes from the maintenance of railroad equipment and track. These wastes would include waste lubricants from equipment and machinery; solvents, paint, and other hazardous material; sanitary waste; and industrial

wastes typical for operations of a small branch rail line. Management and disposition of these wastes would comply with applicable environmental, occupational safety, and public safety regulations. Thus, waste would be handled such that there would be no impacts from rail corridor operations.

There would be no waste management impacts unique to any of the branch rail line implementing alternatives.

6.3.2.2 Specific Impacts of Rail Corridor Implementing Alternatives

6.3.2.2.1 *Caliente Rail Corridor Implementing Alternative*

The Caliente corridor originates at an existing siding to the Union Pacific mainline railroad at Eccles siding near Caliente, Nevada (Figure 2-30). The corridor travels west, traversing the Chief, North Pahroc, Golden Gate, and Kawich Mountain Ranges. The Caliente and Carlin corridors converge near the northwest boundary of the Nellis Air Force Range. Past this point, the corridors are identical. The Caliente corridor is 513 kilometers (319 miles) long from the Union Pacific line connection to the Yucca Mountain site. Figure 6-11 shows the alignment for this corridor, along with possible variations identified by engineering studies (TRW 1999d, page 2, Item 6). The alignment variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. Appendix J assesses the attributes of these alignment variations. This section addresses impacts that would occur along the corridor alignment shown in Figure 6-11. With the exception of the differences identified in Appendix J, the impacts would be generally the same among the possible alignments.

Construction of a branch rail line in the Caliente corridor would require approximately 2.5 years. Construction would take place simultaneously at multiple locations along the corridor. An estimated six construction camps at roughly equal distances along the corridor would provide temporary living accommodations for construction workers and construction support facilities.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those described in Section 6.3.2.1 and are not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

Construction. Table 6-17 summarizes the amount of land required for the Caliente corridor, its ownership, and the estimated amount of land that would be disturbed.

This branch rail line would cross several telephone, pipeline, highway, and power line rights-of-way. It also would cross six Bureau of Land Management grazing allotments (Reveille, Ralston, Stone Cabin, Montezuma, Magruder Mountain, and Razorback), seven wild horse and burro herd management areas, five areas leased for oil and gas exploration and extraction, and four areas designated as available for sale or transfer (TRW 1999f, Table 3).

If DOE decided to build and operate a branch rail line in the Caliente corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies to help ensure that it avoided or mitigated potential land-use conflicts associated with the alignment of a right-of-way. Because Public Law 99-606 withdrew and reserved the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line

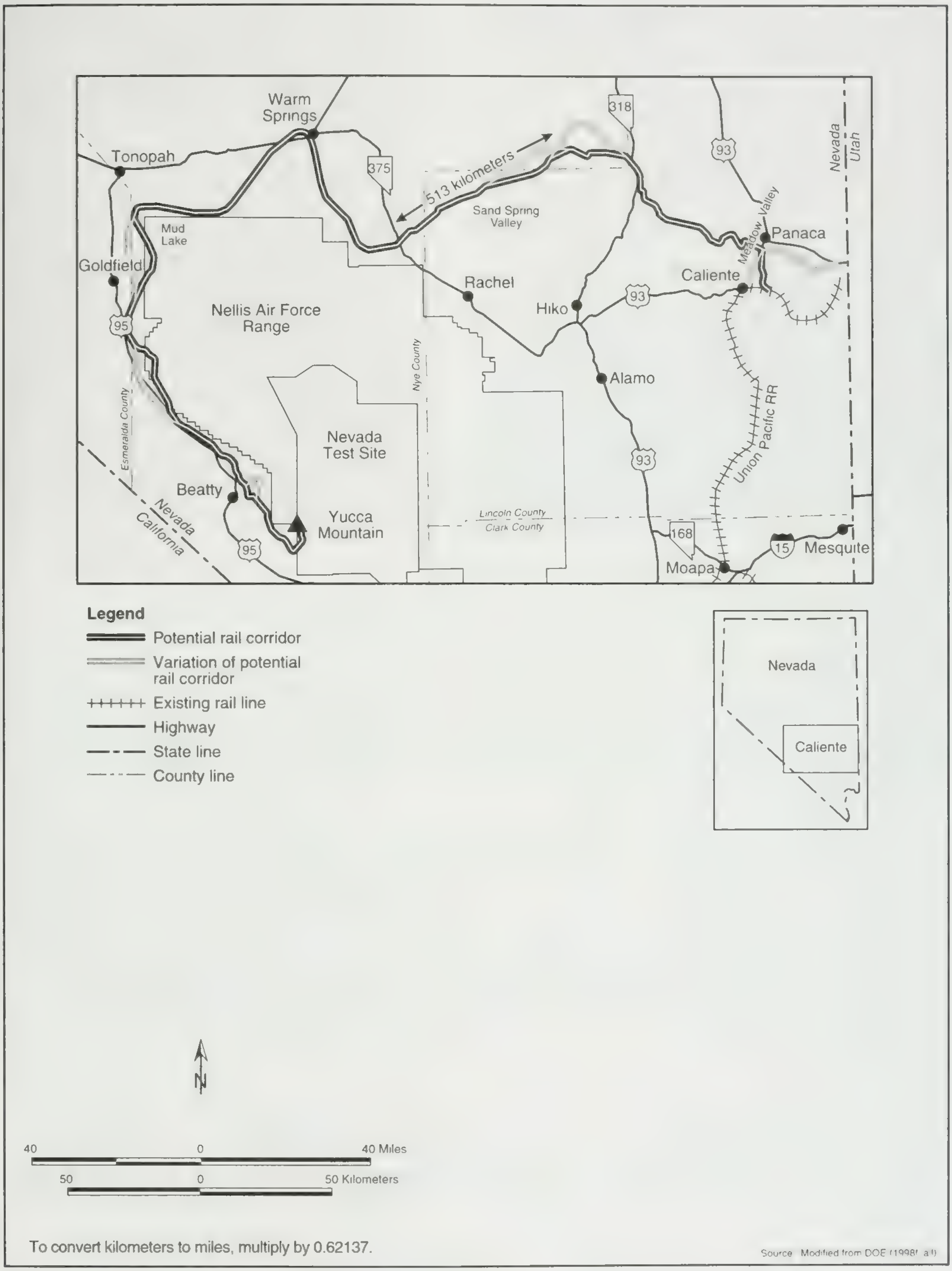


Figure 6-11. Caliente rail corridor.

Table 6-17. Land use in the Caliente rail corridor.

Factor	Amount
Corridor length (kilometers)[a]	513
Land area in 400-meter[b]*-wide corridor (square kilometers)*[c]	210
Land ownership [square kilometers (percent)]	
Bureau of Land Management	180 (88)[d]
Air Force	20 (10)
DOE	4 (2)
Private	Small (~ 1)
Other	None
Disturbed land (square kilometers)	
Inside corridor	14.8
Outside corridor	3.2

a. To convert kilometers to miles, multiply by 0.62137.
b. 400 meters = about 0.25 mile.
c. To convert square kilometers to acres, multiply by 247.1.
d. Percentages do not total 100 due to rounding.

through the Range before DOE could build and operate this line. Alternatively, DOE could choose the corridor variations shown on Figure 6-11 that avoid crossing Nellis Air Force Range lands.

Based on currently available information, DOE is not aware of any conflicts with existing or planned land uses that would occur as a result of construction of a branch rail line in the Caliente corridor. Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Beatty, Caliente, Goldfield, Scotty's Junction, and Warm Springs (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Caliente corridor would require conversion of land within existing grazing allotments and wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. Rail corridor operations would involve the same land-use and ownership considerations as those discussed above for construction. No unique impacts were identified.

Hydrology

Surface Water

Surface-water resources along the Caliente rail corridor are discussed in Chapter 3, Section 3.2.2.1.3, and summarized in Table 6-18. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface water, or the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-18. Surface-water resources along Caliente corridor.[a,b]

Resources in 400-meter[c] corridor			Resources outside corridor within 1 kilometer[d]		
Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
1	4	--[e]	6	--	--

a. Source: reduced from Table 3-35.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. 400 meters = about 0.25 mile.
d. 1 kilometer = about 0.6 mile.
e. -- = none.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which the Caliente rail corridor would pass).

The amount of water needed for the construction of a rail line in the Caliente corridor for soil compaction and dust control would be about 880,000 cubic meters (710 acre-feet) (LeFever 1998a, all). For planning purposes, DOE assumed that this water would come from 64 wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 13,700 cubic meters (11 acre-feet). Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Caliente rail corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration. Table 6-19 summarizes the status of the hydrographic areas associated with the Caliente rail corridor and the approximate portion of the corridor that would pass over Designated Groundwater Basins.

HYDROGRAPHIC AREA

The Nevada Division of Water Planning has divided the State into groundwater basins, or *hydrographic areas*. These areas are used in the management of groundwater resources. Hydrographic areas are generally based on topographic divides (that is, they typically comprise a valley, a portion of a valley, or a terminal basin), but can also be based on administrative divisions. The State classifies a hydrographic area as a Designated Groundwater Basin when the permitted water rights (or appropriations) approach or exceed the area's estimated perennial yield and the water resources are depleted or require additional administration. The Division of Water Planning's home page *http://www.state.nv.us/cnr/ndwp* identifies the hydrographic areas that are Designated Groundwater Basins.

The withdrawal of 13,700 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente rail corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 64 wells along the corridor would mean that many hydrographic areas would have multiple wells. As Table 6-19 indicates, about 40 percent of the corridor length would be over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Table 6-19. Hydrographic areas along Caliente rail corridor.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
18	6	40

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente corridor would require about 47,000 tanker-truck loads of water or about eight truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. There would be no changes in recharge beyond those at the completion of construction.

Biological Resources and Soils

Construction. The construction of a rail line in the Caliente corridor would disturb approximately 18 square kilometers (4,500 acres) of land (Table 6-17). More than 50 kilometers (31 miles) along the southern end of the corridor is in desert tortoise habitat. Assuming that a maximum of about 0.06 square kilometer (15 acres) of land would be disturbed for each kilometer of rail line, construction activities would disturb about 3 square kilometers (740 acres) of desert tortoise habitat, none of which is classified as critical habitat. In addition, these activities could kill individual desert tortoises; however, their abundance is low in this area (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411) so losses would be few. The only other Federally listed species near the corridor is the Railroad Valley springfish (Federally threatened), which has been found about 3 kilometers (1.9 miles) north of the corridor, and it should not be affected. This corridor would cross a portion of the Meadow Valley Wash, which is habitat for the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker. Construction of a branch rail line in this corridor could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Four other special status species occur along this route but could be avoided during land-clearing activities (TRW 1999k, page 3-23) and, therefore, would not be affected.

The rail corridor crosses 13 areas designated as game habitat and 8 areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Wild horses, burros, and game animals near these areas during construction would be disturbed and their migration routes could be disrupted.

At least one spring, one river, and three riparian areas are within the 0.4-kilometer (0.25-mile) corridor (Table 6-18). Although formal delineations have not been conducted, these springs and riparian areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor crosses a number of ephemeral streams that could be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary.

Construction activities would temporarily disturb about 18 square kilometers (4,500 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 18 square kilometers along the 530-kilometer (329-mile)-long corridor would be transitory and small.

Operations. Impacts from operations would include periodic disturbances of wildlife from passing trains and from personnel servicing the corridor. Trains probably would kill individuals of some species but losses would be unlikely to affect regional populations of any species. No additional habitat loss would occur during operations.

Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente branch rail line would be small. The analysis evaluated the potential for impacts in terms of total reportable cases of injury and illness, lost workday cases, and fatality risks to workers and the public from construction and operation activities. Table 6-20 lists these results.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-21 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente rail corridor. Table 6-22 lists the

incident-free impacts, which include transportation along the Caliente corridor and along railways in Nevada leading to a Caliente branch line. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

Construction. There would be socioeconomic impacts associated with construction of a branch rail line in the Caliente corridor. The projected length of the corridor—513 kilometers (319 miles)—is the most important factor for determining the number of workers that would be required. To construct a branch rail line in this corridor would require 560 workers (annual average) (TRW 1999d, Rail Files, Item 1) and 5 construction camps.

Table 6-20. Impacts to workers from industrial hazards during rail construction and operations in the Caliente corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	110	120
Lost workday cases	56	68
Fatalities	1.1	0.2
Noninvolved workers		
Total recordable cases	7	6
Lost workday cases	4	3
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	120	130
Lost workday cases	60	71
Fatalities	1.1	0.23

a. Totals for 2.5 years of construction.
b. Totals for 24 years of operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Table 6-21. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente rail corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction			
Material delivery vehicles	19,000,000	0.3	0.0014
Commuting workers	85,000,000	0.9	0.0061
Subtotals	*104,000,000*	*1.2*	*0.0075*
Operations			
Commuting workers	68,000,000	0.7	0.005
Totals	***172,000,000***	***1.9***	***0.013***

a. To convert kilometers to miles, multiply by 0.62137.

Table 6-22. Health impacts from incident-free Nevada transportation for the Caliente rail corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	210	430
Estimated LCFs[c]	0.09	0.08	0.17
Public			
Collective dose (person-rem)	270	120	390
Estimated LCFs	0.14	0.06	0.20
Estimated vehicle emission-related fatalities	0.00014	0.0018	0.0019

a. Impacts are totals for 24 years (2010 to 2033).
b. Totals might differ due to rounding.
c. LCF = latent cancer fatality.

DOE anticipates that the total direct and indirect employment would peak in 2007 at about 1,200 for the corridor. Population increases in Nevada from the construction of a branch rail line, which would lag behind increases in employment, would peak in 2009 at about 900. Real disposable income, Gross Regional Product, and State and local government expenditures would rise. The expected peak changes due to the Caliente corridor would be increases of $27.7 million in real disposable income, $48.6 million in Gross Regional Product, and $2.5 million in state and local expenditures. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures would be low for Clark and Nye Counties, as would increases in population and State and local government expenditures for Lincoln County. Impacts to employment, real disposable income, and Gross Regional Product in Lincoln County would be moderate compared to baseline values, increasing by about 4 percent, 2 percent, and 2 percent, respectively, in 2007. Although these impacts would be moderate for Lincoln County, they would not exceed historic short-term changes in growth.

Operations. The estimated direct employment for the Caliente branch line operations would be 47 workers. Total direct and indirect peak employment would be 130.

The greatest estimated real disposable income increase attributable to operation, which was projected to occur in 2033, the last year of operation, would be $5.4 million. The increase in Gross Regional Product in 2026, the year in which the increase would be greatest in comparison to the baseline, would be $9.1 million. Annual State and local government expenditures would be much lower than those reported above for construction.

Impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures from the operation of a Caliente branch rail line would be low for Clark and Nye Counties. Peak impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures in Lincoln Country would be moderate compared to baseline values, which would range from a 1.5- to 6.4-percent increase above the baseline. Although these impacts would be moderate for Lincoln County, they would be positive and would not exceed historic short-term changes in growth.

Noise

Most of the corridor would pass through undeveloped Bureau of Land Management land, where the only human inhabitants would be isolated ranchers or persons involved with outdoor recreation. Communities in the region of influence include Caliente, Panaca, Goldfield, and Beatty. Principally because of the populations in these communities, there would be a potential for noise impacts from both construction and operations.

Utilities, Energy, and Materials

Table 6-23 lists the use of fossil fuel and other materials for the construction of a Caliente branch rail line.

Table 6-23. Construction utilities, energy, and materials for a Caliente branch rail line used over 2.5 years.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)[c]
513	42	870	71	420

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.2 *Carlin Rail Corridor Implementing Alternative*

The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada. Figure 6-12 shows the alignment of this corridor along with possible variations identified by engineering studies (TRW 1999d, Rail Files, Item 6). The alignment variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. Appendix J assesses the attributes of these alignment variations. This section addresses impacts that would occur along the corridor alignment shown in Figure 6-12. With the

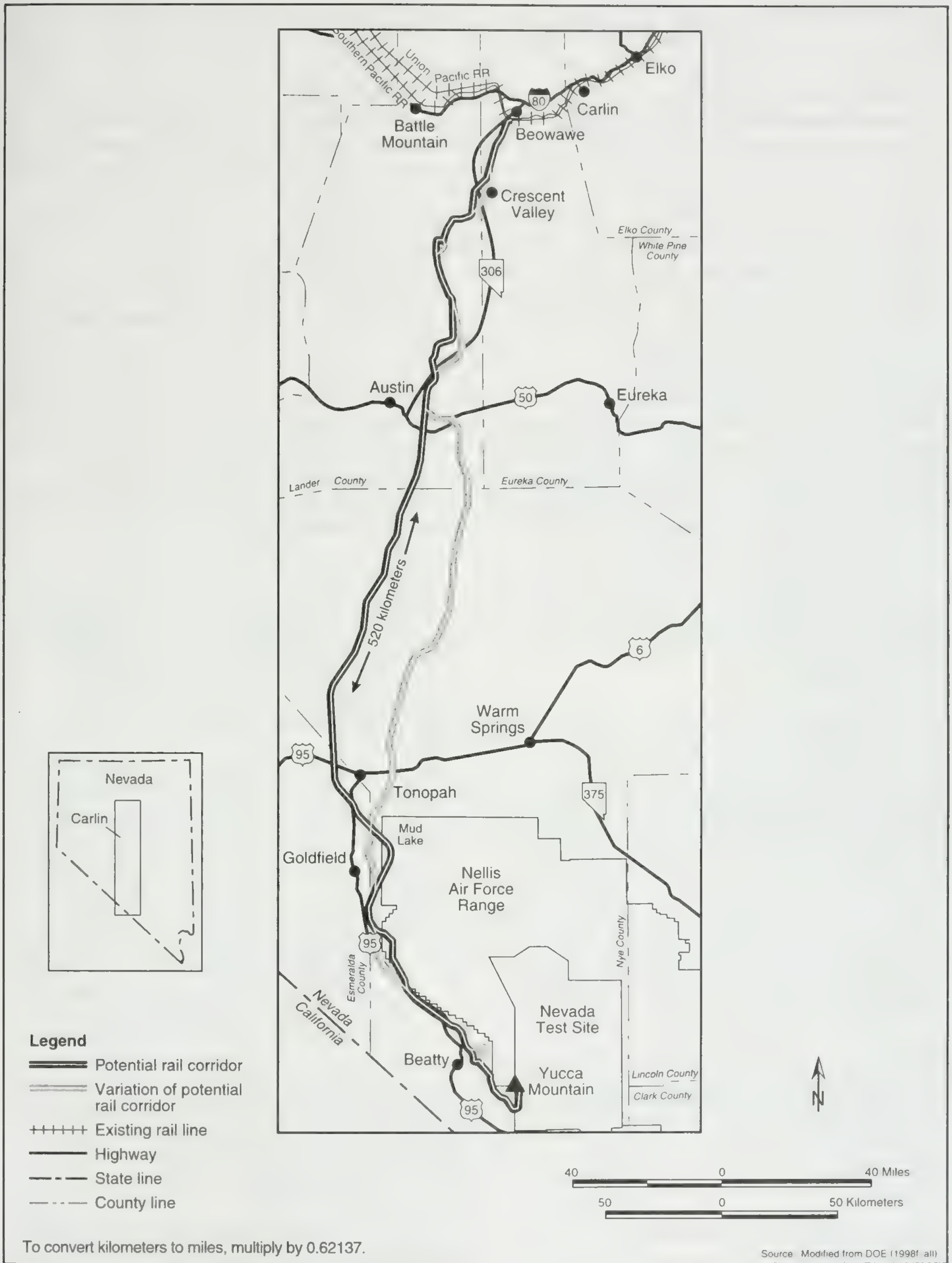


Figure 6-12. Carlin rail corridor.

exception of the differences identified in Appendix J, the impacts would be generally the same among the possible corridor alignments.

The corridor travels south through Crescent, Grass, and Big Smokey Valleys, passing west of the City of Tonopah and east of the City of Goldfield. The corridor then travels south following and periodically crossing the western boundary of the Nellis Air Force Range, passing through Oasis Valley and Beatty Wash. It travels along Fortymile Wash to the proposed repository location. The corridor is about 520 kilometers (323 miles) long from its link with the Union Pacific line to the Yucca Mountain site.

The construction of a branch rail line in the Carlin corridor would require approximately 2.5 years. Construction would take place simultaneously at multiple locations along the corridor. DOE would establish an estimated five construction camps at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those common impacts discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

Construction. Table 6-24 summarizes the amount of land required for the Carlin corridor, its ownership, and the estimated amount of land that would be disturbed.

Table 6-24. Land use in the Carlin rail corridor.

Factor	Amount
Corridor length (kilometers)[a]	520
Land area in 400-meter[b]*-wide corridor (square kilometers)*[c]	210
Land ownership [square kilometers (percent)]	
Bureau of Land Management	180 (85)[d]
Air Force	19 (9)
DOE	4 (2)
Private	7 (3.4)
Other	None
Disturbed land (square kilometers)	
Inside corridor	17
Outside corridor	2

a. To convert kilometers to miles, multiply by 0.62137.
b. 400 meters = about 0.25 mile.
c. To convert square kilometers to acres, multiply by 247.1.
d. Percentages do not total 100 due to rounding.

The corridor crosses several telephone, highway, and utility rights-of-way. It also crosses 12 Bureau of Land Management grazing allotments (Carico Lake, Dry Creek, Grass Valley, Kingston, Simpson Park, Wildcat Canyon, Smoky, Francisco, San Antone, Montezuma, Magruder Mountain, and Razorback) and 5 wild horse and burro herd management areas. Other areas crossed by the corridor include the Bates Mountain antelope release area, three designated riparian habitats, and the Simpson Park habitat management area. It does not cross any oil or gas exploration and extraction areas.

If DOE decided to build and operate a branch rail line in the Carlin corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way. Because Public Law 99-606 withdrew and reserved the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through the Range before DOE could build and operate this line.

Based on currently available information, DOE is not aware of any conflicts with existing or planned land uses that would occur as a result of construction of a branch rail line in the Carlin corridor. Although there are no known community development plans that would conflict with the rail line, the presence of a

rail line could influence future development and land use along the railroad in the communities of Austin, Beatty, Carver's Station, Cortez, Crescent Valley, Gold Acres, Goldfield, Manhattan, Round Mountain, Scotty's Junction, Tenabo, and Tonopah (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Carlin corridor would require conversion of land within existing grazing allotments and wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. Rail corridor operations would involve the same land-use and ownership considerations discussed above for construction. The analysis identified no unique impacts for operations.

Hydrology

Surface Water

Surface-water resources along the Carlin rail corridor are discussed in Chapter 3, Section 3.2.2, and summarized in Table 6-25. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-25. Surface-water resources along Carlin rail corridor.[a,b]

Resources in 400-meter[c] corridor			Resources outside corridor within 1 kilometer[d]		
Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
1	5	--[e]	10	2	1

a. Source: reduced from Table 3-35.
b. Water resources are the number of locations; that is, if a general location has more than one spring, it was counted as one water resource.
c. 400 meters = about 0.25 mile.
d. 1 kilometer = about 0.6 mile.
e. -- = none.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which the Carlin rail corridor passes).

The estimated amount of water needed for the construction of a rail line in the Carlin corridor for soil compaction and dust control would be about 810,000 cubic meters (660 acre-feet) (LeFever 1998a, all). For planning purposes, DOE assumed that this water would come from 67 groundwater wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 12,100 cubic meters (10 acre-feet).

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration. Table 6-26 summarizes the status of the hydrographic areas associated with the Carlin rail corridor, and the approximate portion of the corridor that passes over Designated Groundwater Basins.

Table 6-26. Hydrographic areas along Carlin rail corridor.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
11	5	70

The withdrawal of about 12,000 cubic meters (10 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 67 wells along the corridor would mean that many hydrographic areas would have multiple wells. As indicated in Table 6-26, about 70 percent of the corridor length is in Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean that DOE would truck water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure no adverse effects to groundwater resources.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Carlin corridor would require about 43,000 tanker-truck loads of water or about 9 truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

Biological Resources and Soils

Construction. The construction of a rail line in the Carlin corridor would disturb approximately 19 square kilometers (4,700 acres) (Table 6-24). More than 50 kilometers (31 miles) of its length along the southern end of the corridor occurs in desert tortoise habitat. Construction activities would disturb about 3 square kilometers (740 acres) of this habitat, assuming the maximum rate of 0.06 square kilometer (15 acres) disturbed per linear kilometer of railroad. In addition, construction activities could kill individual desert tortoises; however, the abundance of this species is low in this area (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411) so losses would be few. Three other special status species are found along this route but could be avoided during land-clearing activities and should not be affected.

This rail corridor would cross seven areas designated as game habitat and six areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Wild horses, burros, and game animals near these areas during construction would be disturbed, and their migration routes could be disrupted.

One spring, one river, and five riparian areas are within the 0.4-kilometer (0.25-mile)-wide corridor (Table 6-25). Although no formal delineations have been conducted, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary.

Construction activities would temporarily disturb about 19 square kilometers (4,700 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 19 square kilometers (4,700 acres) along the 520-kilometer (323-mile)-long corridor would be transitory and small.

Operations. Impacts from operations would include periodic disturbance of wildlife from passing trains and from personnel servicing the corridor. Trains probably would kill individuals of some species but losses would be unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts on soils would be small.

Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Carlin branch rail line would be small (see Table 6-27). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities.

Table 6-27. Impacts to workers from industrial hazards during rail construction and operations for the Carlin corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	100	120
Lost workday cases	50	68
Fatalities	1	0.23
Noninvolved workers		
Total recordable cases	6	6
Lost workday cases	3	3
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	110	130
Lost workday cases	53	71
Fatalities	1	0.23

a. Totals for 2.5 years for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-28 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Carlin rail corridor. Table 6-29 lists the incident-free impacts, which would include transportation along the Carlin corridor and transportation along railways in Nevada that led to a Carlin branch line. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Table 6-28. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Carlin rail corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	19,000,000	0.3	0.0014
Commuting workers	76,000,000	0.8	0.0055
Subtotals	*95,000,000*	*1.1*	*0.0068*
Operations[c]			
Commuting workers	68,000,000	0.7	0.005
Totals	***163,000,000***	***1.8***	***0.012***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 2.5 years for construction.
c. Totals for 24 years for operations.

Socioeconomics

Construction. There would be socioeconomic impacts associated with the construction of a branch rail line in the Carlin corridor. The projected length of the corridor, 520 kilometers (323 miles), would determine the number of workers that would be required. The construction of a branch rail line in this corridor would require 500 workers (annual average) (TRW 1999d, Rail Files, Item 1) and 5 construction camps.

Table 6-29. Health impacts from incident-free Nevada transportation for the Carlin corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	250	470
Estimated latent cancer fatalities	0.09	0.11	0.19
Public			
Collective dose (person-rem)	270	150	420
Estimated latent cancer fatalities	0.13	0.08	0.21
Estimated vehicle emission-related fatalities	0.00014	0.0024	0.0025

a. Impacts are totals for 24 years (2010 to 2033).

b. Totals might differ from sums due to rounding.

DOE anticipates that total direct and indirect construction employment would peak in 2007 at about 1,100. Population increases in Nevada from construction, which would lag behind increases in employment, would be likely to peak in 2009. The increase from constructing a Carlin branch rail line would be 790. In addition, real disposable income, Gross Regional Product, and State and local government expenditures would rise. The expected peak changes would be increases of $24.5 million in real disposable income, and $43.5 million in Gross Regional Product in 2007, and $2.2 million in State and local expenditures in 2009. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for construction of a branch rail line in the Carlin corridor would be low for all affected counties.

Operations. Estimated employment for operations in the Carlin corridor would be 47. The total estimated direct and indirect employment from these operations at its peak would be about 140.

The estimated increase in real disposable income in 2029 through 2033 compared to the baseline would be $6.0 million. The increase in Gross Regional Product in 2029 through 2033, the years when the analysis predicted the impacts would be greatest in comparison to the baseline, for the Carlin line would be about $9.4 million. This peak reflects the gradual increase in shipping that would occur over the 24 years of shipping. Annual State and local government expenditures would be much lower than those reported above for construction.

Impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures from operating a Carlin branch rail line would be low for all affected counties.

Noise

Most of the Carlin corridor would pass through undeveloped Bureau of Land Management land, where the only human inhabitants would be isolated ranchers or persons involved with outdoor recreation. There are small communities such as Crescent, Beowawe, and Hadley in the region of influence. For this corridor, noise impacts would be unlikely during construction and operation.

Utilities, Energy, and Materials

Table 6-30 lists the projected use of fossil fuels and other materials in the construction of a Carlin branch rail line.

Table 6-30. Construction utilities, energy, and materials for a Carlin branch rail line used during 2.5 years.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
520	39	800	72	400

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.3 *Caliente-Chalk Mountain Rail Corridor Implementing Alternative*

The Caliente-Chalk Mountain corridor is identical to the Caliente corridor until it reaches the northern boundary of the Nellis Air Force Range. At this point the Caliente-Chalk Mountain corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site. Figure 6-13 shows the alignment of this corridor along with possible variations identified by engineering studies (TRW 1999d, Page 1, Item 1). The alignment variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. Appendix J assesses the attributes of these alignment variations. This section addresses impacts that would occur along the corridor alignment shown in Figure 6-13. With the exception of differences identified in Appendix J, the impacts would be generally the same among the possible corridor alignments. The corridor is 345 kilometers (214 miles) long from its link at the Union Pacific railroad near Caliente to Yucca Mountain.

The construction of a branch rail line in the corridor would require approximately 2.5 years. Construction would take place simultaneously at a number of locations. An estimated four construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

Construction. Table 6-31 summarizes the amount of land required for the Caliente-Chalk Mountain corridor, its ownership, and the estimated amount of land that would be disturbed.

The Caliente-Chalk Mountain corridor would involve several road, power line, and utility rights-of-way before it entered the Nellis Air Force Range and then the Nevada Test Site. Variations of the corridor alignment would provide flexibility to address engineering, land-use, or environmental constraints due to Nevada

Table 6-31. Land use in the Caliente-Chalk Mountain rail corridor.

Factor	Amount
Corridor length (kilometers)[a]	345
Land area in 400-meter[b]*-wide corridor (square kilometers)*[c]	140
Land ownership [square kilometers (percent)]	
BLM	76 (55)[d]
Air Force	22 (16)
DOE	40 (29)
Private	0.8 (0.6)
Other	None
Disturbed land (square kilometers)	
Inside corridor	10
Outside corridor	2

a. To convert kilometers to miles, multiply by 0.62137.
b. 400 meters = about 0.25 miles.
c. To convert square kilometers to acres, multiply by 247.1.
d. Percentages do not total 100 due to rounding.

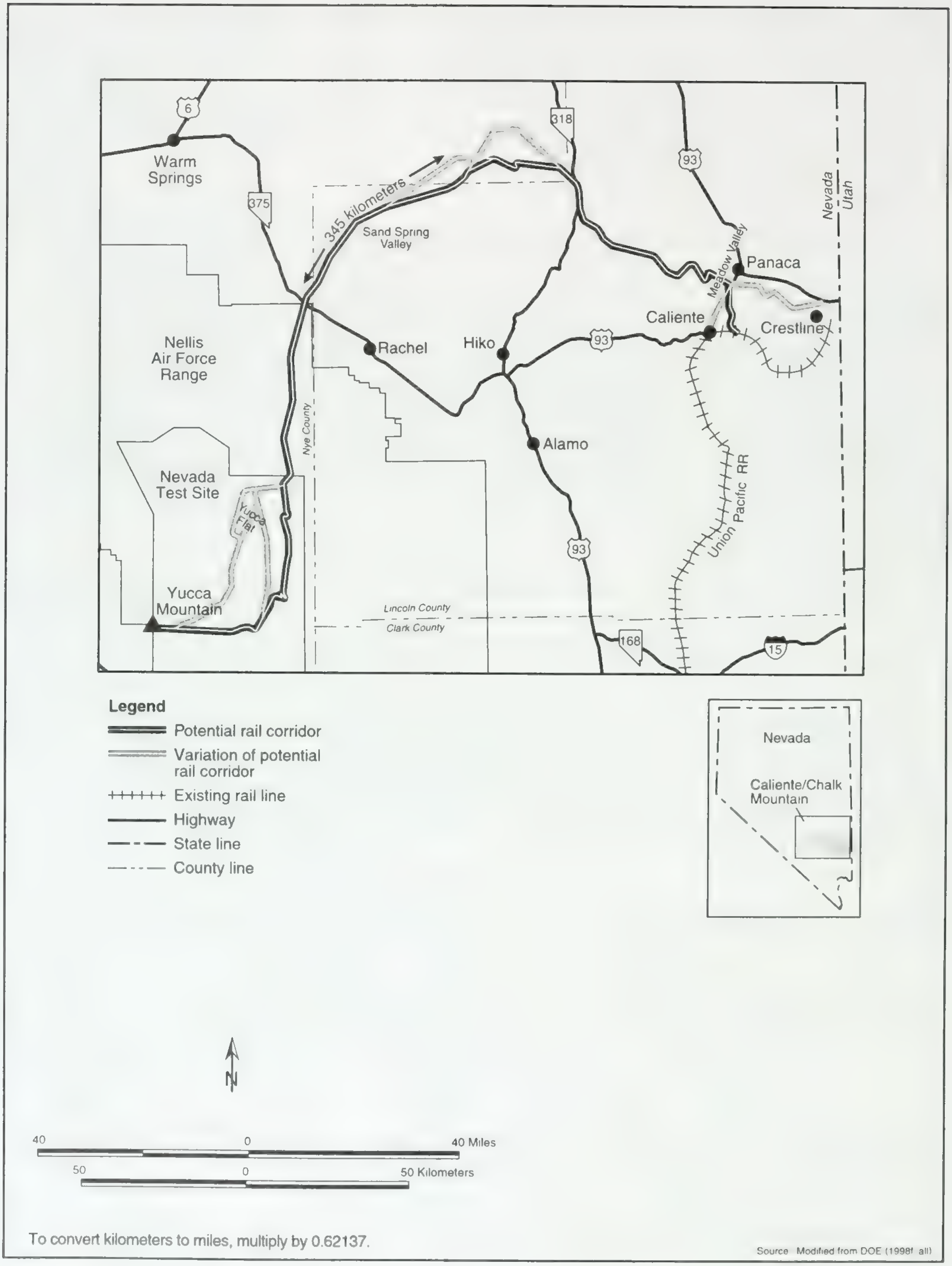


Figure 6-13. Caliente-Chalk Mountain rail corridor.

Test Site surface areas and associated facilities and radiologically contaminated areas. The corridor would also cross five oil and gas leases.

The Caliente-Chalk Mountain corridor would involve the most land controlled by the Nellis Air Force Range, which, according to the Air Force, would affect Air Force operations. Because Public Law 99-606 withdrew and reserved the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through the Range before DOE could build and operate this line. The Air Force has identified national security issues related to a Chalk Mountain route (Henderson 1997, all), citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE regards the route as a "non-preferred alternative."

Hydrology

Surface Water

Chapter 3, Section 3.2.2, discusses surface-water resources along the Caliente-Chalk Mountain corridor; Table 6-32 summarizes these resources. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-32. Surface-water resources along Caliente-Chalk Mountain corridor.[a,b]

Resources in 400-meter[c] corridor			Resources outside corridor within 1 kilometer[d]		
Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
--[e]	2	--	6	--	--

a. Source: reduced from Table 3-35.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. 400 meters = about 0.25 mile.
d. 1 kilometer = about 0.6 mile.
e. -- = none.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Caliente-Chalk Mountain rail corridor passes).

The estimated amount of water needed for construction of a rail line in the corridor for soil compaction and dust control would be about 594,000 cubic meters (480 acre-feet) (LeFever 1998a, all). For planning purposes, DOE assumed that this water would come from 43 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 14,000 cubic meters (11 acre-feet).

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and if the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-33 summarizes the status of the hydrographic areas associated with the Caliente-Chalk Mountain rail corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins.

Table 6-33. Hydrographic areas along Caliente-Chalk Mountain rail corridor.

Hydrographic areas	Designated Groundwater Basins: Number	Designated Groundwater Basins: Percent of corridor length
11	2	30

The withdrawal of about 14,000 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 43 wells along the corridor would mean that many hydrographic areas would have multiple wells. As listed in Table 6-33, about 30 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use well locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources did not receive adverse impacts.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente-Chalk Mountain corridor would require about 32,000 tanker-truck loads of water or about eight truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

Biological Resources and Soils

Construction. The construction of a rail line in the Caliente-Chalk Mountain corridor would disturb about 12 square kilometers (3,000 acres) of land (Table 6-31). About 40 kilometers (25 miles) of the corridor length at its southern end crosses desert tortoise habitat. Assuming that 0.06 square kilometer (15 acres) would be disturbed for each linear kilometer of railroad, construction activities would disturb about 2.4 square kilometers (590 acres) of desert tortoise habitat. Such activities could kill individual desert tortoises; however, their abundance is low in this area (Rautenstrauch and O'Farrell 1998, pages 407 to 411) so losses would be few. This corridor crosses a portion of the Meadow Valley Wash, which is habitat for an unnamed subspecies of the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker (see Chapter 3, Section 3.2.2.1.4). The construction of a branch rail line near Caliente could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Three special status plant species are found along this route but could be avoided during land-clearing activities and should not be affected.

This rail corridor would cross six areas designated as game habitat and two areas designated as wild horse or wild horse and burro management areas. Construction activities would reduce habitat in these areas. Game animals, burros, and horses near areas of active construction would be disturbed and their migration routes could be disrupted.

Two riparian areas are within the 0.4-kilometer (0.25-mile)-wide corridor (Table 6-32). Although no formal delineations have been conducted, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. The corridor also crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work

with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary.

Soils in and adjacent to the corridor would be disturbed on approximately 12 square kilometers (3,000 acres) of land. The impacts of disturbing 12 square kilometers of soil along the 345-kilometer (214-mile)-long corridor would be transitory and small.

Operations. Impacts from operations would include periodic disturbances of wildlife from passing trains and from personnel servicing the corridor. Trains probably would kill individuals of some species but losses would be unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts on soils would be small.

Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente-Chalk Mountain branch rail line would be small (Table 6-34). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers and the public from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur in moving equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-35 lists these results.

Table 6-34. Impacts to workers from industrial hazards during rail construction and operations for the Caliente-Chalk Mountain corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	80	120
Lost workday cases	40	68
Fatalities	0.8	0.23
Noninvolved workers		
Total recordable cases	5	6
Lost workday cases	3	3
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	85	130
Lost workday cases	43	71
Fatalities	0.8	0.23

a. Totals for 2.5 years for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente-Chalk Mountain rail corridor.

Table 6-36 lists the incident-free impacts, which include transportation along the corridor and along railways in Nevada leading to a Caliente-Chalk Mountain branch line. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Table 6-35. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente-Chalk Mountain rail corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	13,000,000	0.2	0.001
Commuting workers	61,000,000	0.6	0.0044
Subtotals	*74,000,000*	*0.8*	*0.0049*
Operations[c]			
Commuting workers	68,000,000	0.7	0.005
Totals	***142,000,000***	***1.5***	***0.01***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 2.5 years for construction.
c. Totals for 24 years for operations.

Table 6-36. Health impacts from incident-free Nevada transportation for the Caliente-Chalk Mountain implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	170	390
Estimated latent cancer fatalities	0.09	0.07	0.16
Public			
Collective dose (person-rem)	270	110	380
Estimated latent cancer fatalities	0.13	0.06	0.19
Estimated vehicle emission-related fatalities	0.00014	0.0016	0.0017

a. Impacts are totals for 24 years (2010 to 2033).
b. Totals might differ from sums of values due to rounding.

Socioeconomics

Construction. There would be socioeconomic impacts associated with the construction of a branch rail line in the Caliente-Chalk Mountain corridor. The length of the corridor, 345 kilometers (214 miles), determines the number of workers that would be required. The construction of a branch rail line in this corridor would require 400 workers and four construction camps (TRW 1999d, Rail Files, Item 1).

Based on analyses it conducted using the Regional Economic Models, Inc., system (REMI 1999, all), DOE anticipates that the total direct and indirect construction employment would peak in 2007 at about 910. Population increases in Nevada from construction, which would lag behind increases in employment, would be likely to peak two years later in 2009. The increase in population attributable to the Caliente-Chalk Mountain corridor would be about 640. Real disposable income, Gross Regional Product, and State and local government expenditures would rise. The expected peak year changes for a branch rail line in the Caliente-Chalk Mountain corridor would be increases of $19.2 million in real disposable income, $34.9 million in Gross Regional Product, and $1.9 million in State and local expenditures. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

The impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for constructing a branch rail line in the Caliente-Chalk Mountain corridor would be low for Clark and Nye Counties, as would increases in population in Lincoln County. Impacts to employment, real disposable income, and Gross Regional Product in Lincoln County would be moderate compared to baseline values ranging from 1 percent to 5.7 percent of the baseline. Although these impacts would be moderate in Lincoln County, they would not exceed historic short-term changes in growth.

Operations. Estimated employment for operations in the Caliente-Chalk Mountain corridor would be 47. The estimated peak total direct and indirect employment from these operations would be about 120.

The greatest estimated real disposable income increase attributable to the operation of the Caliente-Chalk Mountain branch line, which was projected to occur in 2033, would be $4.9 million. The increase in Gross Regional Product in 2029, the year in which increases would be greatest as a percentage of the baseline, would be $8.6 million. Annual State and local government expenditures would be much lower than those for construction.

The impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures from operating a Caliente-Chalk Mountain branch rail line would be low for Clark and Nye Counties. Impacts to employment, population, real disposable income, State and local government expenditures, and Gross Regional Product in Lincoln County would be moderate compared to baseline values ranging from about 1.5 percent to 6.4 percent of the baseline. These impacts would be moderate for Lincoln County; they would not exceed historic short-term changes in growth.

Noise

Almost half of the Caliente-Chalk Mountain corridor is on Nellis Air Force Range and Nevada Test Site land, where community response to noise would not be an issue. The communities of Caliente and Panaca could be affected. Because the corridor passes through or near these communities, it could have noise impacts from both construction and operation.

Utilities, Energy, and Materials

Table 6-37 lists the use of fossil fuels and other materials in the construction of a Caliente-Chalk Mountain branch rail line.

Table 6-37. Construction utilities, energy, and materials for a Caliente-Chalk Mountain branch rail line.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete thousand metric tons)
345	33	630	48	280

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.4 *Jean Rail Corridor Implementing Alternative*

The Jean corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada. It travels northwest, passing near the Towns of Pahrump and Amargosa Valley before reaching the Yucca Mountain site. The corridor is about 181 kilometers (112 miles) long from its link at the Union Pacific line to the site. Figure 6-14 shows the alignment of this corridor along with possible variations identified by engineering studies (TRW 1999d, page 1, Item 6). The alignment variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. Appendix J assesses the attributes of these alignment variations. This section addresses impacts that would occur along the corridor alignment shown in Figure 6-14. With the exception of differences identified in Appendix J, the impacts would be generally the same among the possible corridor alignments.

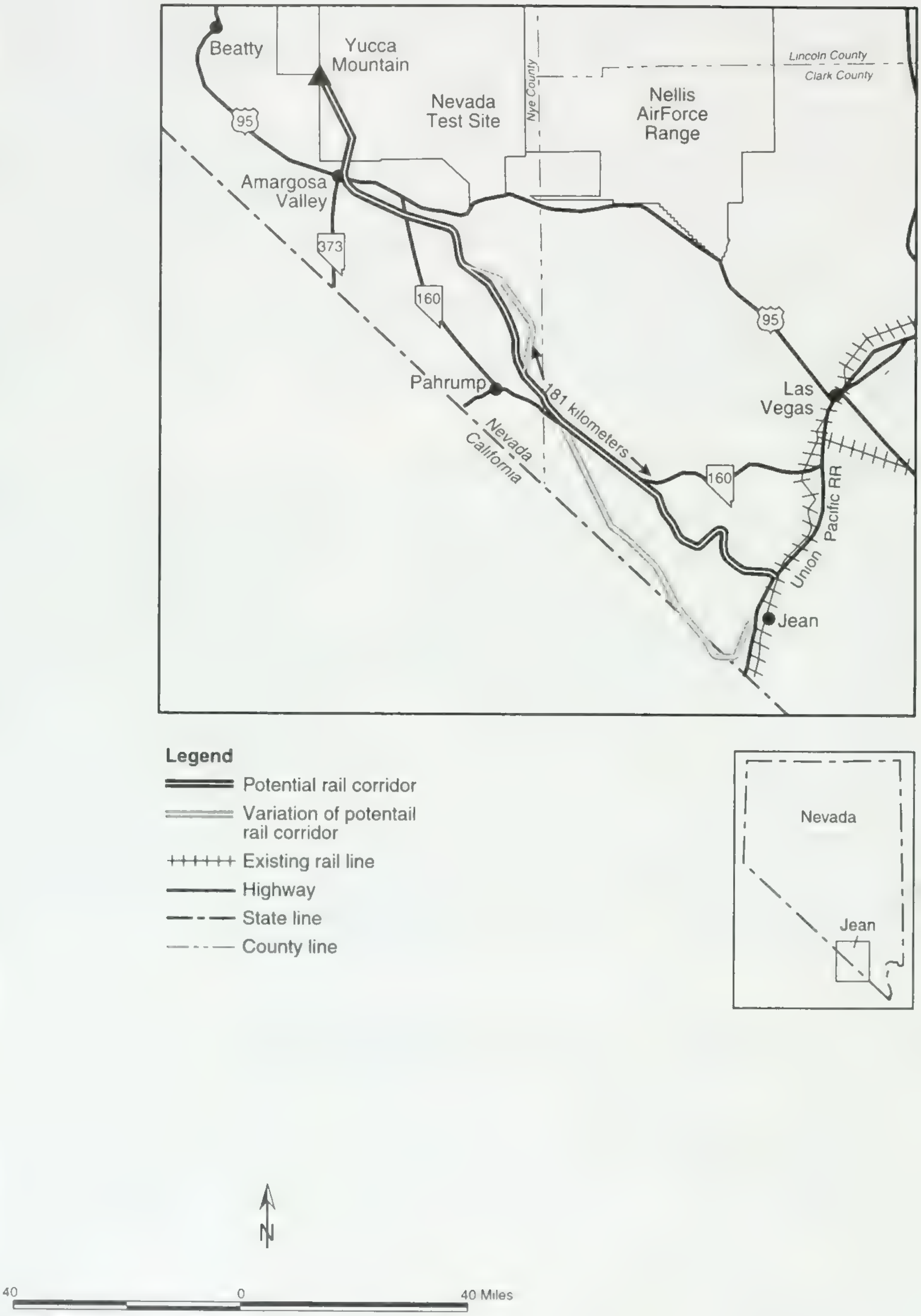
The construction of a branch rail line in the corridor would require approximately 2.5 years. Construction would take place simultaneously at a number of locations. An estimated two construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology, including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

Construction. Table 6-38 summarizes the amount of land required for the Jean corridor, its ownership, and the estimated amount of land that would be disturbed.

The corridor crosses eight Bureau of Land Management grazing allotments (Mount Stirling, Spring Mountain, Stump Springs, Table Mountain, Wheeler Wash, and three unnamed and unallotted areas); two wild horse and burro herd management areas (both in Pahrump Valley); the Old Spanish Trail Mormon Road special recreation management area; and four areas designated as available for sale or transfer. It



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DOE (1998f, all)

Figure 6-14. Jean rail corridor.

Table 6-38. Land use in the Jean rail corridor.

Factor	Amount
Corridor length (kilometers)[a]	181
Land area in 400-meter[b]-wide corridor (square kilometers)[c]	72
Land ownership [square kilometers (percent)]	
Bureau of Land Management	60 (83)
Air Force	None
DOE	8.5 (12)
Private	3.6 (5)
Other	None
Disturbed land (square kilometers)	
Inside corridor	6.5
Outside corridor	2.5

a. To convert kilometers to miles, multiply by 0.62137.
b. 400 meters = about 0.25 mile.
c. To convert square kilometers to acres, multiply by 247.1.

also crosses several telephone, pipeline, highway, and power line rights-of-way. It is within 1.6 kilometers (1 mile) of the Toiyabe National Forest and three mines (Bluejay, Snowstorm, and Pilgram). In the vicinity of Pahrump, a rail line in the Jean corridor could conflict with town growth.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Jean rail corridor by private interest. If encroachment occurred, conflicts could result as impediments to the full use of the land. Areas most likely for use by private interests are those already privately owned and those that are currently designated for sale or transfer by the Bureau of Land Management.

If DOE decided to build and operate a branch rail line in the Jean corridor, it would consult with the Bureau of Land Management and other affected agencies to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way.

Based on currently available information, DOE is not aware of any conflicts with existing or planned land uses that would occur as a result of construction of a branch rail line in the Jean corridor. Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Amargosa Valley, Goodsprings, Jean, Johnnie, and Pahrump (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Jean corridor would require conversion of land within existing grazing allotments and wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. Rail corridor operations would involve the same land-use and ownership considerations discussed above for construction. No unique impacts for operations were identified.

Hydrology

Surface Water

Chapter 3, Section 3.2.2, notes that there are no surface-water resources along the Jean rail corridor.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Jean corridor passes).

The estimated amount of water needed for construction of a rail line in the corridor for soil compaction and dust control would be about 500,000 cubic meters (410 acre-feet) (LeFever 1998a, all). For planning purposes, DOE assumed that this water would come from 23 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 22,000 cubic meters (18 acre-feet).

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-39 summarizes the status of the hydrographic areas associated with the Jean rail corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins.

Table 6-39. Hydrographic areas along Jean rail corridor.

Hydrographic areas	Designated Groundwater Basins: Number	Designated Groundwater Basins: Percent of corridor length
6	5	90

The withdrawal of 22,000 cubic meters (18 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 23 wells along the corridor would mean that several of the hydrographic areas would have multiple wells. As indicated in Table 6-39, about 90 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Jean corridor would require about 27,000 tanker-truck loads of water or about 14 truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

Biological Resources and Soils

Construction. Approximately 9 square kilometers (2,200 acres) of land would be disturbed during the construction of a rail line in the Jean corridor (Table 6-38). This corridor passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 9 square kilometers of desert tortoise habitat. Construction activities could kill individual desert tortoises. Desert tortoise abundance is low along much of this corridor; however, some areas in the Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have higher abundance (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). Two other special status species are found along this route but could be avoided during land-clearing activities and should not be affected.

This rail corridor crosses ten areas designated as game habitat and three areas designated as wild horse and burro management areas (TRW 1999k, page 3-28). Construction activities would reduce habitat in these areas. Wild horses, burros, and game animals near these areas during construction would be disturbed and their migration routes could be disrupted.

No springs, perennial streams, or riparian areas occur along this corridor. The corridor crosses a number of ephemeral streams that may be waters of the United States, although no formal delineations have been conducted (TRW 1999k, page 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary.

Soils in and adjacent to the corridor would be disturbed on approximately 9 square kilometers (2,200 acres) during construction of a railroad. This impact to soils along the 181-kilometer (110-mile)-long corridor would be transitory and small.

Operations. Impacts from operations would include periodic disturbances of wildlife from passing trains and from personnel servicing the corridor. Trains probably would kill individuals of some species but losses would be unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts on soils would be small.

Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Jean branch rail line would be small (Table 6-40). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-41 lists these results.

Table 6-40. Impacts to workers from industrial hazards during rail construction and operations for the Jean corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	68	95
Lost workday cases	34	52
Fatalities	0.7	0.2
Noninvolved workers		
Total recordable cases	4	4
Lost workday cases	2	2
Fatalities	0	0
Totals		
Total recordable cases	72	99
Lost workday cases	36	54
Fatalities	0.7	0.2

a. Totals for 2.5 years for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in using the Jean rail corridor. Table 6-42 lists the incident-free impacts, which include transportation along the corridor and along railways in Nevada leading to a Jean branch line. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Table 6-41. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Jean rail corridor.

Jean	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Materials delivery vehicles	10,000,000	0.2	0.00072
Commuting workers	52,000,000	0.5	0.0038
Subtotals	*62,000,000*	*0.7*	*0.0045*
Operations[c]			
Commuting workers	52,000,000	0.5	0.0038
Totals	***114,000,000***	***1.2***	***0.0082***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 2.5 years for construction.
c. Totals for 24 years for operations.

Table 6-42. Health impacts from incident-free Nevada transportation for the Jean corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	180	400
Estimated latent cancer fatalities	0.09	0.07	0.16
Public			
Collective dose (person-rem)	270	160	430
Estimated latent cancer fatalities	0.13	0.08	0.21
Estimated vehicle emission-related fatalities	0.00014	0.014	0.014

a. Impacts are totals for 24 years (2010 to 2033).
b. Totals might differ from sums of values due to rounding.

Socioeconomics

Construction. There would be socioeconomic impacts associated with the construction of a branch rail line in the Jean corridor. The projected length of the corridor, 181 kilometers (112 miles), determines the number of workers that would be required. The construction of a branch rail line in this corridor would require about 340 workers and 2 construction camps (TRW 1999d, Rail Files, Item 1).

DOE anticipates that the total direct and indirect employment would peak in 2007 at about 720. Population increases in Nevada, which would lag behind increases in employment, would be likely to peak in 2009. The estimated increase attributed to the Jean corridor would be about 530. Real disposable income, Gross Regional Product, and State and local government expenditures would also rise. The expected changes would be increases of about $16.3 million in real disposable income, about $29 million in Gross Regional Product, and about $1.4 million in State and local expenditures. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

The impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for constructing a branch rail line in the Jean corridor would be low for all counties affected.

Operations. Estimated employment for operations in the Jean corridor would be 36. The total estimated direct and indirect employment from these operations would be about 70.

The greatest estimated real disposable income increase attributable to the operation of a Jean branch line would occur in 2024 and would be about $3.1 million. The increase in Gross Regional Product in 2025, the year in which impacts would be greatest, would be about $6.0 million. Annual State and local government expenditures would be much lower than those reported for construction.

The impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures from operating a Jean branch rail line would be low for all counties affected.

Noise

The Jean corridor would pass the small communities of Amargosa Valley, Goodsprings, Jean, and Pahrump. In addition, the potential for development in the Las Vegas area and the fact that the corridor passes through private land could lead to noise impacts during both construction and operation because of the relatively large number of potential nearby inhabitants.

Utilities, Energy, and Materials

Table 6-43 lists the use of fossil fuels and other materials in the construction of a Jean branch rail line.

Table 6-43. Construction utilities, energy, and materials for a Jean branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Jean	181	26	500	26	150

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.5 *Valley Modified Rail Corridor Implementing Alternative*

The Valley Modified corridor originates near the existing Apex rail siding off the Union Pacific mainline railroad. It travels northwest passing north of the City of Las Vegas, north of the Town of Indian Springs, parallel to U.S. 95 before entering the southwest corner of the Nevada Test Site and reaching the Yucca Mountain site. The corridor is about 159 kilometers (98 miles) long from its link with the Union Pacific line to the site. Figure 6-15 shows the alignment of this corridor along with possible variations identified by engineering studies (TRW 1999d, page 1, Item 6). The alignment variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. Appendix J assesses the attributes of these alignment variations. This section addresses impacts that would occur along the corridor alignment shown in Figure 6-15. With the exception of differences identified in Appendix J, the impacts would be generally the same among the possible corridor alignments.

The construction of a branch rail line in the corridor would require approximately 2.5 years. Construction would take place simultaneously at a number of locations along the corridor. Two construction camps would be established to provide temporary living accommodations for construction workers and construction support facilities.

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Table 6-44. Land use in the Valley Modified rail corridor.

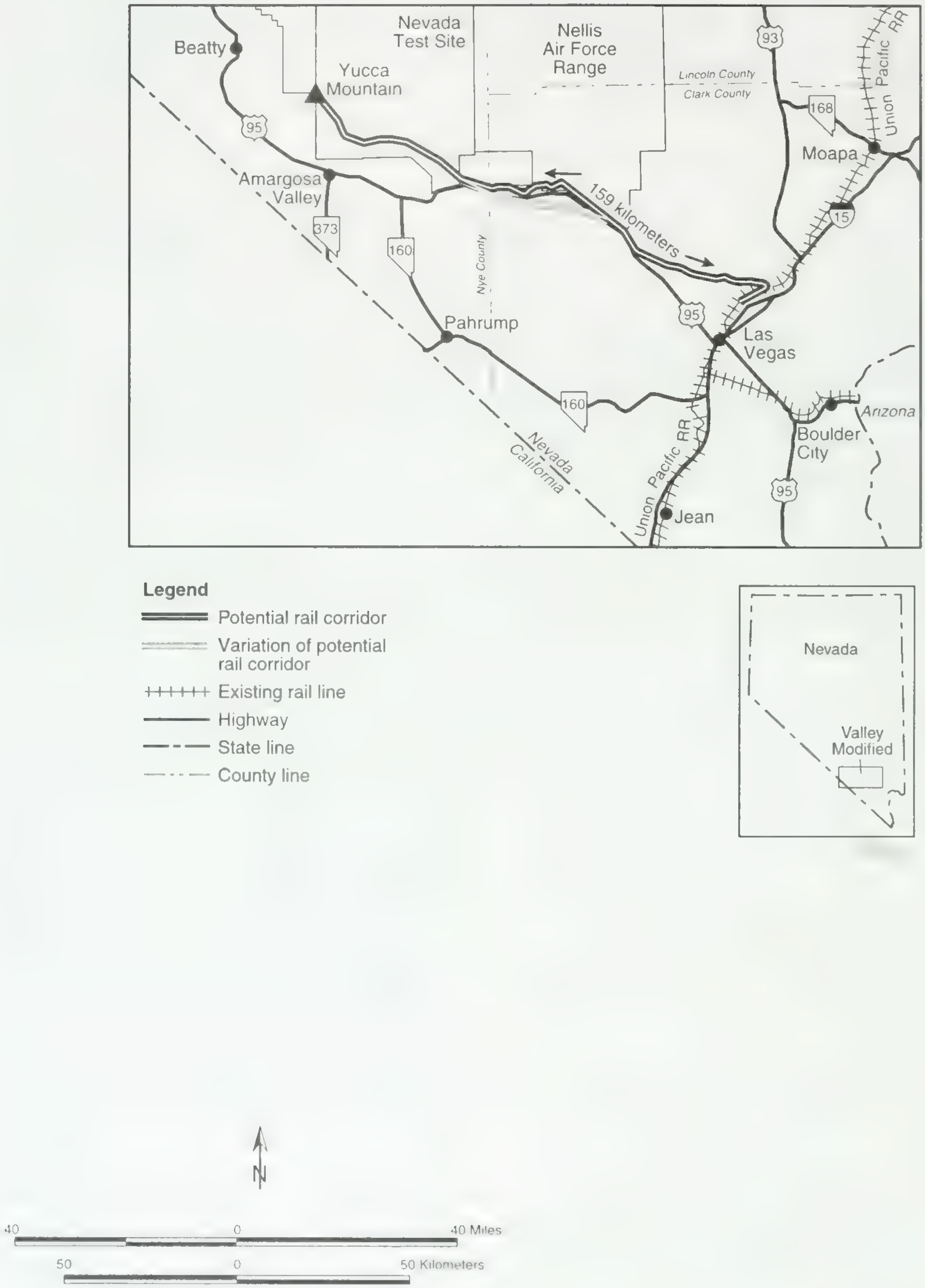
Factor	Amount
Corridor length (kilometers)[a]	159
Land area in 400-meter[b]-wide corridor (square kilometers)[c]	64
Land ownership [square kilometers (percent)]	
Bureau of Land Management	32 (50)
Air Force	10 (15)
DOE	21 (35)
Private	None
Other	None
Disturbed land (square kilometers)	
Inside corridor	4.4
Outside corridor	0.6

a. To convert kilometers to miles, multiply by 0.62137.
b. 400 meters = about 0.25 mile.
c. To convert square kilometers to acres, multiply by 247.1.

Land Use and Ownership

Construction. Table 6-44 summarizes the amount of land required for the Valley Modified corridor, its ownership, and the estimated amount of land that would be disturbed.

The corridor crosses three Bureau of Land Management grazing allotments (Wheeler Slope, Indian Springs, and Las Vegas Valley), two wilderness study areas (Nellis ABC and Quail Spring, both recommended by the Bureau as unsuitable for inclusion in the National Wilderness System), and one area designated as available for sale or transfer (TRW 1999f, Table 7). It also crosses several telephone, pipeline, highway, and power line rights-of-way, and the Nellis Air Force Base small arms range.



To convert kilometers to miles, multiply by 0.62137.

Figure 6-15. Valley Modified rail corridor.

The corridor also passes along the Las Vegas metropolitan area's northern boundary, in an area that is currently undergoing growth and where future commercial and residential growth might occur. However, metropolitan area growth might not extend to the corridor area until after the operations phase of the repository when there would no longer be a need for a branch rail line. The corridor also passes within about 1.6 kilometers (1 mile) of the Las Vegas Paiute Indian Reservation north of Las Vegas.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Valley Modified rail corridor by private interests. If encroachment occurred, conflicts could result as impediments to the full use of lands. Areas most likely for use by private interests are those currently designated for sale or transfer by the Bureau of Land Management.

If DOE decided to build and operate a branch rail line in the Valley Modified corridor, it would consult with the Bureau of Land Management, U.S. Air Force, other affected agencies, and other DOE program operations on the Nevada Test Site to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way.

Based on currently available information, DOE is not aware of any conflicts with existing or planned land uses that would occur as a result of construction of a branch rail line in the Valley Modified corridor. Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Indian Springs and North Las Vegas (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Valley Modified corridor would require conversion of land within existing grazing allotments and wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. Rail corridor operations would involve the same land-use and ownership considerations discussed above for construction. No unique impacts for operations were identified.

Air Quality

Construction. The Valley Modified rail corridor would involve construction in the Las Vegas Valley airshed, which is in nonattainment for particulate matter (PM_{10}) and carbon monoxide (FHWA 1996, pages 3-53 and 3-54). To assess nonradiological air quality impacts from branch line construction in this airshed, DOE reviewed the environmental impact statement that Clark County prepared for the construction of the Northern and Western Las Vegas Beltway project.

An evaluation of environmental impacts of the construction of the Las Vegas Beltway observed that Federal air quality conformity criteria require that "[t]he project must not cause or contribute to new violations and/or increase the severity of existing carbon monoxide and PM_{10} violations" (FHWA 1996, page 4-38). The EIS for the Las Vegas Beltway project commented that "the study area is largely undeveloped at this time. Carbon monoxide Urban Airshed Modeling by the Clark County Department of Comprehensive Planning has shown that the area substantially affected by the project has low existing ambient carbon monoxide concentration levels."

In relation to PM_{10}, the Clark County EIS states (FHWA 1996, page 4-38):

> *[t]he Clark County Health District, Air Pollution Control division has an extensive array of particulate matter and fugitive dust control and mitigation regulations. Transportation facility construction in the Las Vegas Valley must comply with these Health District requirements. The Tier 2 EIS will address those dust control and mitigation measures appropriate to the facility's design concept and scope. The Health District's PM_{10} emissions control measures will be included in the final plans, specifications and estimates for the development of a facility within the selected corridor.*

The total amount of land disturbed by the construction of a branch rail line in the Valley Modified corridor would be approximately the same as that disturbed by the construction of the Northern and Western Las Vegas Beltway. As a consequence, air quality impacts from branch rail line construction activities in the Las Vegas Valley airshed would be less than those for the beltway project. If DOE selected the Valley Modified corridor for the construction and operation of a branch rail line, the final plans, specifications, and estimates would include the Clark County Health District PM_{10} emissions control measures.

Operations. Fuel consumption by diesel train engines operating along the rail corridor would emit carbon monoxide, nitrogen dioxide, and particulate matter (PM_{10} and $PM_{2.5}$). Based on the Federal standards for locomotives (EPA 1997a, page 3), there would be no significant emissions of sulfur dioxide.

In attainment areas, the pollutant concentrations in the air would increase slightly during the passage of a train, but the emissions from one or two trains a day would not exceed the ambient air quality standards. However, the Valley Modified rail corridor would include a route through the Las Vegas Valley airshed, which is in nonattainment for carbon monoxide and PM_{10}. The air quality impacts to this airshed from train operation along the Valley Modified rail corridor would be a small contribution in comparison to the amount of pollutants emitted by automotive travel in the basin. Thus, emissions from train operations in the Las Vegas Valley airshed would not produce further violations of the ambient air quality standards.

Hydrology

Surface Water

Chapter 3, Section 3.2.2, notes that there are no surface-water resources along the Valley Modified corridor.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Valley Modified corridor passes).

The estimated amount of water needed for construction of a rail line in the Valley Modified corridor for soil compaction and dust control would be about 395,000 cubic meters (320 acre-feet) (LeFever 1998a, all). For planning purposes, DOE assumed that this water would come from 20 groundwater wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 20,000 cubic meters (16 acre-feet). Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Valley Modified rail corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-45 summarizes the designation status of the hydrographic areas associated with the Valley Modified rail corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins.

Table 6-45. Hydrographic areas along Valley Modified rail corridor.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
6	3	70

The withdrawal of 20,000 cubic meters (16 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 20 wells along the corridor would mean that hydrographic areas would have multiple wells. As indicated in Table 6-45, about 70 percent of the

corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Valley Modified corridor would require about 21,000 tanker-truck loads of water or about 20 truckloads each day. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

Biological Resources and Soils

Construction. The construction of a rail line in the Valley Modified corridor would disturb approximately 5 square kilometers (1,200 acres) of land (Table 6-44). This corridor passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 5 square kilometers of desert tortoise habitat. Construction activities could kill individual desert tortoises. However, desert tortoise abundance is low along this corridor (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411) so losses would be few. Populations of two special status plant species occur along the corridor but could be avoided during land-clearing activities and should not be affected.

There is one herd management area but no designated game habitat along this corridor (TRW 1999k, page 3-29). Construction activities would reduce habitat in this area. Wild horses and burros near this area during construction would be disturbed and their migration routes could be disrupted.

No springs, perennial streams, or riparian areas occur along this corridor. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States, although no formal delineations have been conducted (TRW 1999k, page 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, if necessary.

Soils in and adjacent to the corridor would be disturbed on approximately 5 square kilometers (1,200 acres) of land during construction of the railroad. Impacts to 5 square kilometers (1,200 acres) of soils along the 159-kilometer (99-mile)-long corridor would be transitory and small.

Operations. Impacts from operations would include periodic disturbance of wildlife from passing trains and from personnel servicing the corridor. Trains probably would kill individuals of some species but losses would be unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

Cultural Resources

Construction. Because no systematic field studies have been completed for any of the rail corridors, specific impacts to culturally important sites, areas, or resources cannot be determined at this time.

The Valley Modified corridor would pass by the Las Vegas Paiute Indian Reservation in the northeastern part of the Las Vegas Valley. The corridor would not affect identified cultural resources on the reservation. If construction activities identified sites or resources important to Native Americans in the future, either in or near a right-of-way, adverse effects could occur. DOE would consult with Native American officials to develop appropriate mitigations for such impacts.

Operations. No additional direct or indirect impacts on archeological and historic sites or to Native American resources, traditional cultural properties, or ethnic cultural values from rail operation have been identified.

Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Valley Modified branch rail line would be small (Table 6-46). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available (Table 6-47).

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Valley Modified rail corridor. Table 6-48 lists the incident-free impacts, which include transportation along the Valley Modified corridor and along railways in Nevada leading to a Valley Modified branch line. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Table 6-46. Impacts to workers from industrial hazards during rail construction and operations for the Valley Modified corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved worker		
Total recordable cases[c]	32	95
Lost workday cases	16	52
Fatalities	0.3	0.2
Noninvolved worker		
Total recordable cases	2	4
Lost workday cases	1	2
Fatalities	0	0
Totals		
Total recordable cases	34	99
Lost workday cases	17	54
Fatalities	0.3	0.2

a. Totals for 2.5 years for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injuries and illness.

Table 6-47. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Valley Modified rail corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	7,000,000	0.1	0.00054
Commuting workers	24,000,000	0.3	0.0017
Subtotals	*31,000,000*	*0.4*	*0.0022*
Operations[c]			
Commuting workers	52,000,000	0.5	0.004
Totals	***84,000,000***	***0.9***	***0.006***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 2.5 years for construction.
c. Totals for 24 years for operations.

Table 6-48. Health impacts from incident-free Nevada transportation for the Valley Modified corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	160	380
Estimated latent cancer fatalities	0.09	0.06	0.15
Public			
Collective dose (person-rem)	270	110	380
Estimated latent cancer fatalities	0.13	0.06	0.19
Estimated vehicle emission-related fatalities	0.00014	0.0017	0.0018

a. Impacts are totals for 24 years (2010 to 2033).
b. Totals might differ from sums of values due to rounding.

Socioeconomics

Construction. There would be socioeconomic impacts associated with the construction of a branch rail line in the Valley Modified corridor. The length of the corridor, 159 kilometers (98 miles), determines the number of workers that would be required. The construction of a branch rail line in this corridor would require 160 workers and 2 construction camps (DOE 1999d, Rail Files, Item 1).

DOE anticipates that the total direct and indirect construction employment would peak in 2007 at about 335. Population increases in Nevada would be likely to peak two years later in 2009. The estimated peak increase attributed to building a Valley Modified branch rail line would be about 240. Real disposable income, Gross Regional Product, and State and local government expenditures would also rise. The expected changes for the Valley Modified corridor would be increases of about $8.1 million in real disposable income, $13.9 million in Gross National Product, and $600,000 in State and local expenditures. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

The impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for building a branch rail line in the Valley Modified corridor would be low for the affected counties.

Operations. Estimated employment for operation of a Valley Modified branch rail line would be 36. Total estimated direct and indirect employment from these operations would be about 57 at its peak.

Estimated real disposable income increase attributable to operations would be greatest in 2033, the last year of operation, and would be about $2.4 million. The increase in Gross Regional Product in 2029, when impacts would be greatest in comparison to the baseline, would be about $5.4 million. Annual State and local government expenditures would be lower than those reported above for construction.

The impacts to employment, population, real disposable income, gross regional product, and State and local government expenditures from operating a Valley Modified branch rail line would be low for the affected counties.

Noise

Because of the large population in the Las Vegas Valley, this corridor would have a potential for noise impacts in the region north of Las Vegas, particularly as urban growth moves in that direction. In addition, Indian Springs could receive noise impacts from this option.

Utilities, Energy, and Materials

Table 6-49 lists the use of fossil fuels and other materials in the construction of a Valley Modified branch rail line.

Table 6-49. Construction utilities, energy, and materials for a Valley Modified branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Valley Modified	159	13	270	22	130

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.3 IMPACTS OF NEVADA HEAVY-HAUL TRUCK TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five implementing alternatives that would employ heavy-haul trucks to transport rail shipping casks containing spent nuclear fuel and high-level radioactive waste in Nevada. DOE has identified five highway routes in Nevada for potential use by the heavy-haul trucks to transport the casks. The casks would be transported to the repository from an intermodal transfer station along a mainline railroad where they would be loaded onto the heavy-haul trucks from railcars. The trucks would also transport empty casks from the repository back to the intermodal transfer station for loading back onto railcars. DOE would locate an intermodal transfer station at one of three potential locations in Nevada near existing rail lines and highways: (1) near Caliente, (2) northeast of Las Vegas (Apex/Dry Lake), or (3) southwest of Las Vegas (Sloan/Jean). Caliente is the originating location for three of the routes that heavy-haul trucks could use to ship spent nuclear fuel and high-level radioactive waste to the repository. There is one potential route each associated with the Apex/Dry Lake and Sloan/Jean locations (Figure 6-16).

For convenience and as shown in the figure, the five highway routes have been named the Caliente, Caliente-Chalk Mountain, Caliente-Las Vegas, Apex/Dry Lake, and Sloan/Jean routes. DOE considers these routes to be feasible for heavy-haul trucks to use in transporting large rail casks to and from the repository. The routes were compiled from a selection of highways in Nevada that the State has designated for use by heavy-haul trucks (TRW 1999d, Request #046). They include highways that were identified in a study by the College of Engineering at the University of Nevada, Reno, for the Nevada Department of Transportation (Ardila-Coulson 1989, all). This study provided a "preliminary identification of Nevada highway routes that could be used to transport current shipments of Highway Route-Controlled Quantities of Radioactive Materials and high-level radioactive waste." They also include highways studied by the Transportation Research Center at the University of Nevada, Las Vegas, that characterized "rail and highway routes which may be used for shipments of high-level nuclear waste to a proposed repository at Yucca Mountain, Nevada" (Souleyrette, Sathisan, and di Bartolo 1991, all).

This section evaluates impacts in Nevada for each route and associated intermodal transfer station. The evaluation addresses (1) upgrading highways to accommodate frequent heavy-haul truck shipments, (2) constructing and operating an intermodal transfer station, and (3) making heavy-haul truck shipments. With the exception of Interstate System Highways, upgrades to existing Nevada highways would be necessary to accommodate the heavy-haul trucks.

The analysis of impacts for each of the five Nevada heavy-haul truck implementing alternatives assumed the national mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from nine commercial generators that do not have the capability to handle or

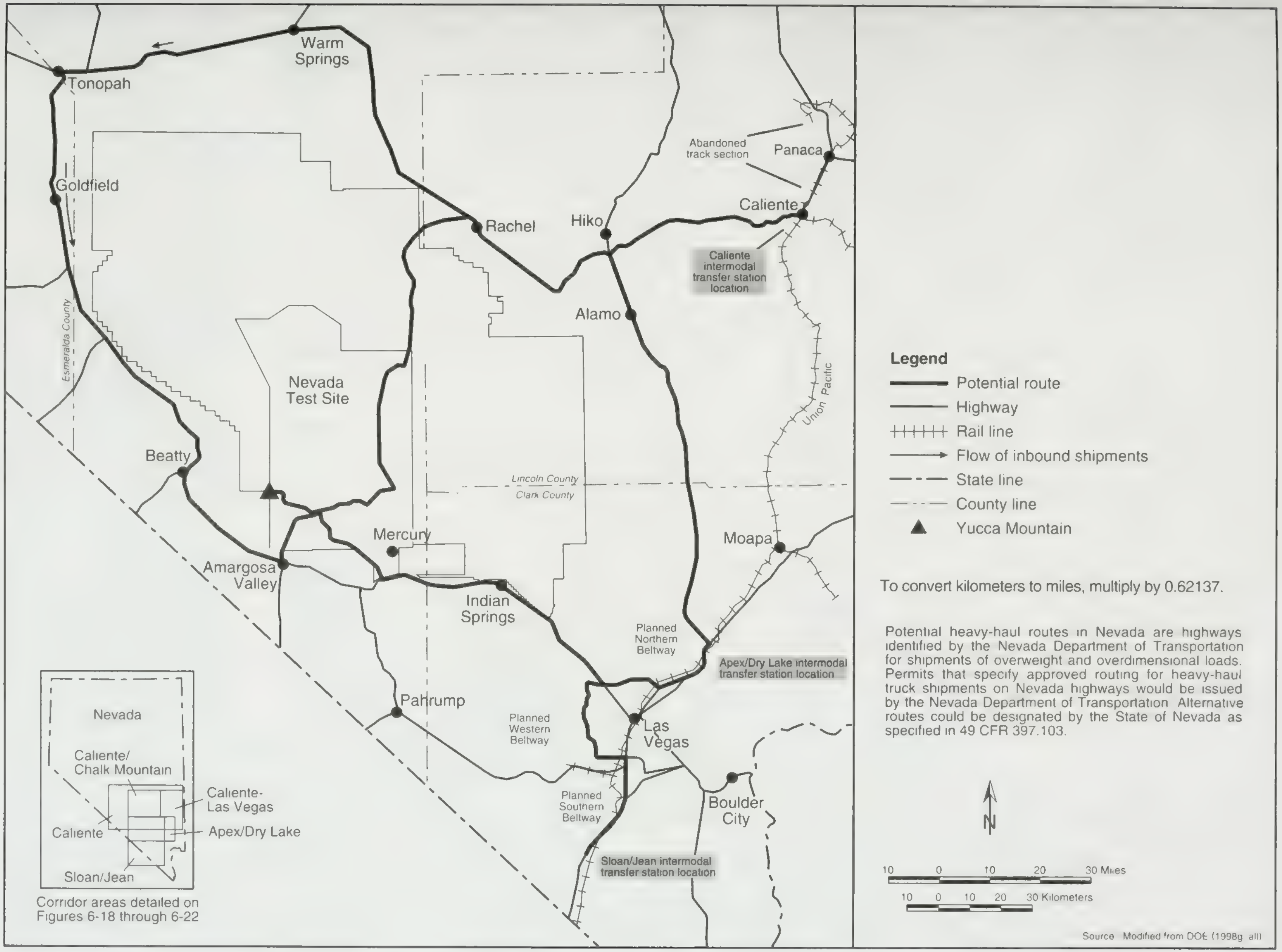


Figure 6-16. Potential routes in Nevada for heavy-haul trucks.

load a large rail cask. About 2,600 legal-weight truck shipments would enter Nevada and travel to the repository. These trucks would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those for the mostly legal-weight truck scenario discussed in Section 6.3.1.

The analysis evaluates impacts for the following environmental resource areas: land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise; aesthetics; utilities, energy, and materials; and waste management.

Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.1 Impacts Common to Nevada Heavy-Haul Truck Implementing Alternatives

Nevada highways upgraded for heavy-haul truck use would allow routine, safe use in year-round operations. Upgrades would include reconstruction of some highway sections, especially in areas where spring and fall thaws and freezes make the highways susceptible to damage by heavy vehicles (frost-restricted areas). In addition, new turnout lanes at frequent intervals along two-lane highways would allow other traffic to pass the slower heavy-haul vehicles. Highway shoulders would be widened and road surfaces would be improved in many areas. Interstate highways would not be improved because they already meet standards that upgrades to other Nevada highways for heavy-haul truck shipments would follow.

Even with the highway upgrades, heavy-haul trucks would cause delays for other vehicles because of their size and slower travel speeds. On most of the highways in Nevada that heavy-haul shipments would use, traffic volumes are classified as *level of service Class A* (DOE 1998m, page 3-11), which means that traffic flows freely without delay (see Chapter 3, Section 3.2.2.2.11, for a description of all levels of service). The addition of 11 one-way trips each week to the traffic flow on these highways would not lead to a change in the average level of service. However, some traffic in lanes traveling with the vehicles would experience delays and short queues could form between turnout areas. In congested areas, such as the Las Vegas metropolitan area, where the level of service for the planned Las Vegas Beltway could be Class C or lower during non-rush-hour times, large slow-moving vehicles with their accompanying escort vehicles could present a temporary but large obstruction to traffic flow. Because disruptions on congested highways often continue after the removal of the cause, the duration of a traffic flow disruption would be longer than the time the vehicle would travel on the highway.

An intermodal transfer station would be common to all five heavy-haul truck implementing alternatives. Figure 6-17 shows the locations in Nevada that DOE is considering for such a station. Station construction would take about 1.5 years. The station would be a fenced area of about 250 by 250 meters (820 by 820 feet) and a rail siding that would be about 2 kilometers (1.25 miles) long. The estimated total area occupied by the facility and support areas would be 200,000 square meters (50 acres). It would

INTERMODAL TRANSFER STATION AND NAVAL SPENT NUCLEAR FUEL

Under the mostly legal-weight truck scenario, DOE would use the services of a commercial intermodal operator for the transfer of naval spent nuclear fuel shipments. This EIS assumed that DOE would not build an intermodal transfer station to handle those shipments. Because only 300 naval spent nuclear fuel casks would arrive in Nevada by rail over 24 years, the impacts of intermodal transfer operations would be considerably less than those for the mostly rail scenario. On average, the intermodal transfers would occur for about 2 weeks every 5 months to remove five casks from each train shipment. A staff of 20 would work only during these rail shipments.

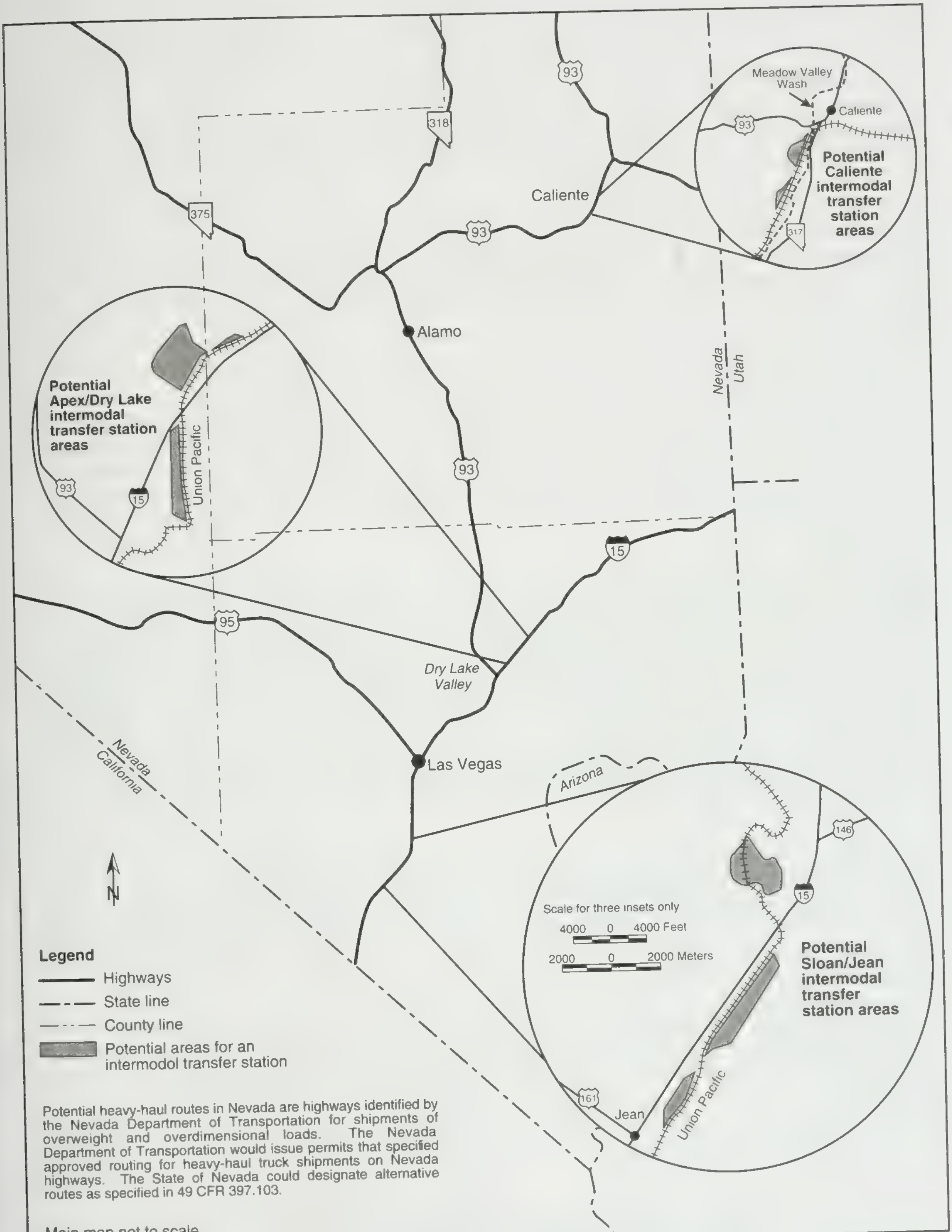


Figure 6-17. Potential locations for an intermodal transfer station.

include rail tracks, two shipping cask transfer cranes (one on a gantry rail and a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connecting tracks to an existing mainline railroad and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. The station would have the capacity to allow an intermodal transfer rate of 22 rail casks a week (11 loaded casks to the repository, 11 empty casks returned to the commercial and DOE sites).

Operations at an intermodal transfer station would include switching railcars carrying spent nuclear fuel and high-level radioactive waste casks from mainline railroad trains to the station's side track; queuing railcars on the side track for movement to the intermodal transfer area; moving railcars carrying loaded casks from the side track into position to transfer the casks to heavy-haul trucks; and using the facility crane to transfer loaded casks from railcars to heavy-haul trucks. The station would reverse this sequence of operations for empty casks returning from the repository.

This section discusses impacts for the analysis areas that would be common to all five heavy-haul truck implementing alternatives. It includes impacts for upgrading Nevada highways for use by heavy-haul trucks, constructing and operating an intermodal transfer station, and heavy-haul truck transportation of shipping casks, both loaded and empty. DOE evaluated these impacts as described in Section 6.3. Section 6.3.3.2 discusses impacts that would be unique to each heavy-haul truck transportation implementing alternative.

Land Use and Ownership

Highway Construction. With the exception of about 2 kilometers (1.2 miles) of new highway near Beatty, Nevada, for the Caliente route, upgrades to Nevada highways for use by heavy-haul trucks would involve improvements to existing roads and bridges. Areas disturbed by these activities would be adjacent to existing highway rights-of-way. Therefore, land disturbance would be limited to widening existing road shoulders by about 2 meters (6.6 feet), adding truck-lane pull-outs at intervals along the route, and increasing the height of overpasses. Borrow material (earth, gravel, and rock) to perform the initial upgrades would come largely from existing Nevada Department of Transportation facilities. Except for highways on the Nellis Air Force Range or Nevada Test Site, that Department would direct the highway improvements.

Intermodal Transfer Station Construction. Land-use impacts from an intermodal transfer station would center around the station because the railroad lines and the highways that DOE would use already exist and their intended use would not change. The construction of an intermodal transfer station would change the land uses and organizational control of about 0.2 square kilometer (50 acres) of property. This land would become the responsibility of DOE or possibly a transportation operating company. The rail line and station fencing could create barriers to wildlife and public access.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Intermodal transfer station operations (arriving and departing trains, arriving and departing heavy-haul trucks, intermodal transfers, and maintenance and inspection activities) would be confined to the same areas that were disturbed during construction, so no additional disturbance would take place. Other land-use conflicts during the operation of an intermodal transfer station would be associated with fences that could create barriers to the movement of livestock and wildlife. Such restrictions would occur for any of the areas evaluated.

Only limited land-use impacts would result from heavy-haul truck operations on Nevada highways. Erosion along these highways would be managed as it is now. Because additional road construction would not be needed, additional land and soil disturbance would not occur.

Other land-use and ownership impacts differ among the implementing alternatives. These impacts are described in Section 6.3.3.2.

Air Quality

Highway Construction. Fuel consumption during construction activities would result in releases of criteria pollutants [carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10} and $PM_{2.5}$). Construction activities would also release particulate matter in the form of fugitive dust from such activities as excavation and truck traffic. Most of the road upgrades would occur in areas that are in attainment for all criteria pollutants. Road upgrade activities along the routes selected for heavy-haul truck use (including construction of a midroute stopover for routes originating in Caliente) would increase pollutant concentrations in the areas near the upgrade. However, because construction would be a moving source along various portions of the route, emissions would be transient and spread over a very large area.

Intermodal Transfer Station Construction. Table 6-50 lists estimated annual emissions from the construction of an intermodal transfer station. These estimates would apply to each of the three potential site areas. During station construction, fuel use by heavy equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{10}, and $PM_{2.5}$. Excavation and truck traffic would result in releases of particulate matter in the form of fugitive dust. The amount of fugitive dust would depend on the amount of disturbed land. Building the intermodal transfer station would disturb about 0.2 square kilometer (50 acres). The analysis assumed that construction activities would affect only 10 percent of the total disturbed land area at any time.

Table 6-50. Annual criteria pollutant releases from construction of an intermodal transfer station (kilograms per year).[a]

Pollutant	Construction emission (annual)	GCR[b] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	3,400	NA[c]	NA
Sulfur dioxide	320	NA	NA
Carbon monoxide	2,100	91,000	2.3
PM_{10}	31,000	64,000 (serious)	48

a. To convert kilograms to tons, multiply by 0.00110023.
b. GCR = General Conformity Rule (40 CFR 93). Applies for releases of pollutants in areas in nonattainment.
c. NA = not applicable.

Table 6-50 lists the percentage of each pollutant in relation to the General Conformity Rule emission threshold. The estimated annual releases from the construction of the intermodal transfer station would be 48 percent of the General Conformity Rule emission threshold (see 40 CFR 93) for PM_{10} and 2.3 percent for carbon monoxide.

Ozone would not be directly released during the construction of the intermodal transfer station. However, ozone precursors (nitrogen dioxide and volatile organic carbon compounds) would be released due to fuel use by construction equipment. The estimated annual emission rates of nitrogen dioxide and volatile organic carbon compounds would be small (40 CFR 52.21). The construction of the intermodal transfer facility, therefore, would not be a significant source of ozone.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Fuel use by heavy-haul trucks would result in emissions of carbon monoxide, nitrogen dioxide, and PM_{10}. Based on the Federal standards for heavy-duty trucks (EPA 1997b, pages E-1 to E-3), emission of sulfur dioxide is not of concern. In attainment areas, the pollutant concentration in the area around the route would increase slightly during the passage of the trucks but would not exceed the standards.

Table 6-51 lists estimated annual emissions from the operation of an intermodal transfer station. These estimates would apply to each location. The station would emit carbon monoxide, nitrogen dioxide, and PM_{10} from the operation of a yard locomotive. Based on Federal standards for locomotives (EPA 1997b, page 73), emissions of sulfur dioxide are not included among emissions of greatest concern.

Table 6-51. Annual emissions of criteria pollutants from operation of an intermodal transfer station over 24 years (kilograms per year).[a]

Pollutant	Operation[b] emissions (annual)	PSD limit[c]	Percent of PSD limit	GCR[d] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	34,000	230,000	15	NA[e]	NA
Sulfur dioxide	(f)	230,000	(f)	NA	NA
Carbon monoxide	8,600	230,000	3.8	91,000	9.4
Particulate matter (PM_{10})	980	230,000	0.43	64,000	1.5

a. To convert kilograms to tons, multiply by 0.0011023.
b. Operations emissions from a switchyard locomotive and heavy-haul trucks.
c. PSD limit Prevention of Signification Deterioration definition of a major stationary source (40 CFR 52.21); applies for releases of criteria pollutants during operation.
d. GCR = General Conformity Rule (40 CFR Part 93); applies for releases of pollutants in areas in nonattainment.
e. NA = not applicable.
f. Sulfur dioxide from locomotives is not included among emission constituents of greatest concern (EPA 1997b, page 73).

The estimated annual releases for the operation of the intermodal transfer station would be about 15 percent or less of the definition of a major stationary source (see Chapter 3, Section 3.1.2.1, or 40 CFR 52.21). The operation of a midroute stopover would result only in small releases of pollutants.

The operation of a yard locomotive would not emit ozone directly, but would emit ozone precursors (nitrogen dioxide and hydrocarbons). The estimated annual releases of the ozone precursors would be small; nitrogen dioxide would be about 15 percent of a major stationary source. Therefore, DOE does not expect the operation of the intermodal transfer facility to be a significant source of ozone.

Because the shipping casks would not be opened, there would be no radiological air quality impacts from normal operations at an intermodal transfer station.

Other air quality impacts would differ among the implementing alternatives (see Section 6.3.3.2).

Hydrology

This section describes impacts common to the five heavy-haul truck implementing alternatives (including upgrades to Nevada highways and construction of a midroute stopover and an intermodal transfer station at one of three locations) for surface water and groundwater.

Surface Water

Highway Construction. For road improvement work and construction of a midroute stopover, a contractor could place fuel tank trucks or trailers along the route to support equipment operations. Such a practice would present some potential for spills and releases. As long as the contractor met the regulatory requirements for reporting and remediating spills and properly disposing of or recycling used materials, the probability of unrecovered spills due to negligence or improper work practices would be low. If a release occurred, the potential for chemical contaminants (principally petroleum products) to enter flowing surface water before cleanup would be the largest risk.

A portable asphalt plant to support roadway improvement work would be located along the paving area. Aggregate crushing plants would be located in borrow areas. DOE assumes that the borrow areas would be those normally used by the Nevada Department of Transportation. Spills and releases of asphalt

materials, which are predominantly petroleum products but include chemical additives, could occur in the course of operating an asphalt plant. Spill reporting and remediation requirements would be in place for these operations, as described above. Once asphalt was in place, it would be susceptible to minor leaching or bleeding while it cured, similar to the leaching or bleeding that occurs during road construction for other highway projects.

Intermodal Transfer Station Construction. Potential impacts to surface water would include (1) the possible spread of contamination by precipitation, intermittent runoff events, or, where present, releases to flowing water in the single perennial stream, and (2) the alteration of natural drainage patterns or runoff rates that could affect downgradient resources.

Materials that could contaminate surface water would be present during construction; these would consist primarily of petroleum products (fuels and lubricants) and coolants (antifreeze) to support equipment operations. There would not be much bulk storage of these materials. Fuel for vehicles would be purchased from nearby commercial vendors. Minor amounts of building materials such as paints, solvents, and thinners could be present during construction.

The construction of an intermodal transfer station would include stormwater runoff control, as necessary; the completed station would have a stormwater detention basin. These measures would minimize the potential for contaminated runoff to reach a stream.

Appendix L contains a floodplain/wetlands assessment that examines the effects of highway route construction, operation, and maintenance on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. There are no delineated wetlands at Yucca Mountain.

If DOE selected heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would also select one of five routes (Figure 6-16) and one of three alternative intermodal transfer station sites (Figure 3-17). DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternatives. The assessment in Appendix L presents a comparison of what is known about the floodplains, springs, and riparian areas along the five alternative routes for heavy-haul trucks and at the three alternative intermodal transfer station sites. In general, wetlands have not been delineated along the alternative highway routes or at the three alternative intermodal transfer station sites.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Surface-water impacts during operations would be limited to those from maintaining and resurfacing highways and parking areas at a midroute stopover that the heavy-haul trucks would use. As discussed above, good construction practices overseen by the Nevada Department of Transportation would limit impacts that could result from spills of chemical contaminants in the course of highway maintenance and resurfacing activities. Contamination of surface water caused by contaminants leached from new asphalt would be similar to that which occurs in the periodic resurfacing of asphalt highways.

Operations at a completed intermodal transfer station would have little impact on surface waters beyond any permanent drainage alterations that occurred during construction. The station area runoff rates would differ from those of the natural or existing terrain but, given the relatively small size [0.2 square kilometer (50 acres)] of the potentially affected area, they would add little to overall runoff quantities for the area.

The general design criteria for a station would consider the potential for a 100-year flood. Because the spent nuclear fuel and high-level radioactive waste shipping casks would not be opened or otherwise disassembled, the use of industrial design standards for this facility would be appropriate. The analysis

assumes that the station would have a diesel-powered generator to provide standby electric power and an associated diesel storage tank. The diesel tank would present a minor potential for spills and releases. Runoff retention areas would limit impacts of potential oil and diesel spills in parking areas.

Groundwater

Highway Construction. For highway upgrades, the most likely impacts would be changes to infiltration rates and new sources of contamination that could migrate to groundwater during construction. In this case, however, the potential for impacts would be small due to the relatively small areas affected by upgrading and the fact that highway construction [with the exception of 2 kilometers (1.2 miles) of new highway near Beatty, Nevada, and a midroute stopover], would be a modification of existing roadways. In addition, there would be no large sources of contamination.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this impact would be minor and short-lived as contractors completed their work and stabilized the disturbed areas.

Intermodal Transfer Station Construction. Construction activities for an intermodal transfer station would disturb and loosen the ground for some time, which could cause higher infiltration rates. However, this impact would be minor and short-lived as contractors completed the facility and stabilized the disturbed areas.

Water needs for construction would be met by trucking water to the site, installing a well (which would also be used for operations), or possibly by connection to a local water distribution system. In any case, water demand would be small for construction.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The use of highways by heavy-haul trucks would have little impact on groundwater resources. There would be no continued need for water along the route, and there would be no changes to recharge beyond those at the completion of construction.

The operation of a completed midroute stopover and an intermodal transfer station would have little impact on groundwater. Infiltration rates would be as described above for the completion of construction; the relatively small size of the facilities would minimize changes. Potential sources of contamination at the intermodal transfer station would consist primarily of a diesel fuel tank for the standby generator and heavy equipment. Water demand at the station and the midroute stopover would be small, consisting primarily of the needs of the operators, and would be obtained by the methods described above for construction. This demand would cause no noticeable change in water consumption rates for the area.

Other impacts to hydrology would differ among the implementing alternatives, as described in Section 6.3.3.2.

Biological Resources and Soils

Highway Construction. Highway upgrade activities would involve improving existing road surfaces and possibly building a bridge near Beatty, Nevada (Caliente route), a midroute stopover (Caliente routes), and about 2 kilometers (1.2 miles) of new highway to handle heavier vehicles (TRW 1999d, Request #048). Areas disturbed by these activities would be in, adjacent to, or near existing rights-of-way. These areas would consist of habitats previously degraded by human activities, which would limit impacts associated with the routes. Slight alterations of habitat immediately adjacent to existing roads would have only small impacts on desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than a kilometer on either side of roads having average daily traffic greater than 180 vehicles (Bury and Germano 1984, pages 57 to 72). The modification of bridges

and culverts over perennial streams, if necessary, could temporarily disrupt stream flow and increase sedimentation in downstream aquatic environments. DOE anticipates that preconstruction surveys of potentially disturbed areas would identify and locate sensitive biological resources and best management practices would minimize the impacts of highway upgrades.

All of the heavy-haul truck implementing alternatives cross perennial or ephemeral streams that may be classified as jurisdictional waters of the Unites States. Discharge of dredged or fill material into those waters is regulated under Section 404 of the Clean Water Act. After the selection of a heavy-haul truck implementing alternative, if requested, DOE would assist the Nevada Department of Transportation to identify any jurisdictional waters of the United States that highway upgrades would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters; and obtain, as appropriate, an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the mitigation plan and complying with other permit requirements, the Nevada Department of Transportation would ensure that impacts to wetlands and other waters of the United States would be small.

The primary soil impacts from improvements to highways would be land disturbance. Road improvements would consist of widening existing roadways, constructing turnouts and truck lanes at designated stretches along the routes, and improving existing intersections. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. Drainage control along the route probably would remain as it is now. These combined measures would minimize the potential for adverse impacts to soils.

Intermodal Transfer Station Construction. The biological settings of the three potential sites for an intermodal transfer station differ; Section 6.3.3.2 addresses impacts for each of the Nevada heavy-haul transportation implementing alternatives.

Soil impacts from the construction of an intermodal transfer station would arise primarily from the direct impacts of land disturbance and would apply to each station site and route. Table 3-41 lists estimates of land area required for an intermodal transfer station. The disturbed areas probably would be subject to increased erosion for at least some of the construction phase. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. At the beginning of station construction, the topsoil would be stripped and stockpiled; during construction, temporary erosion control systems would minimize erosion impacts. At the completion of construction, the topsoil would be replaced over areas not used for station facilities, the area disturbed surrounding the station would be revegetated, and other permanent erosion control systems would be installed as appropriate.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Impacts to biological resources from operations along any of the five possible routes would be very small. Because existing roadways would not be greatly altered, operations and maintenance would not lead to additional habitat losses. Heavy-haul truck operations could kill individuals of some species, but losses would be unlikely to have a detectable impacts on the regional population of any species and would be small in comparison to losses caused due to other traffic on the highways. Passing trucks could disrupt wildlife, but such effects would be transitory. The use of an upgraded highway would have only a small impact on soils.

Impacts to biological resources from operations at an intermodal transfer station and a midroute stopover would be very small. Operations would not lead to additional habitat losses. Individuals of some species could be disturbed or killed by human activities at the station and stopover, but such losses would be unlikely to have a detectable impacts on the regional population of any species.

The use of a completed intermodal transfer station and midroute stopover should have only small impacts on soils. The station and stopover would be maintained throughout the operations period, including the repair of erosion damage to the grounds around the station and the rail siding.

Other impacts to biological resources would differ among the heavy-haul truck implementing alternatives, as described in Section 6.3.3.2.

Cultural Resources

Highway and Intermodal Transfer Station Construction. Impacts could occur, primarily from surface-disturbing activities, to archaeological, historic, and traditional Native American cultural sites from upgrading highways, constructing a midroute stopover, and building an intermodal transfer station. Limited cultural resource inventories have been performed along the potential routes, and no systematic ethnographic field studies have been completed near the potential sites for an intermodal transfer station.

For example, there are four known archaeological sites near each of the Caliente and the Apex/Dry Lake intermodal station locations; none of these eight sites has been evaluated for eligibility for the *National Register of Historic Places*.

Therefore, specific impacts to culturally important sites, areas, or resources cannot be determined at this time. For the selected route and intermodal transfer station location, the Nevada Department of Transportation and DOE would perform specific archaeological surveys for proposed ground-disturbing activities. Such studies would occur during the development of the engineering design and before highway improvements or station construction began.

Heavy-Haul Truck and Intermodal Transfer Station Operations. No additional direct or indirect impacts would be likely to archaeological and historic sites from the operation of an intermodal transfer station or along highways from operations of heavy-haul trucks. Nonetheless, and although existing highways would be used, Native Americans have expressed great concern about the transport of spent nuclear fuel and high-level radioactive waste through tribal lands and through the larger region that comprises their traditional holy lands (AIWS 1998, all). Use of the Caliente-Las Vegas, Apex/Dry Lake, or Sloan/Jean route would include travel on U.S. 95 across a 1.6-kilometer (1-mile) section of the Las Vegas Paiute Indian Reservation. The Caliente-Las Vegas and Apex/Dry Lake routes pass near the Moapa Indian Reservation.

There are no known cultural resource impacts unique to any of the implementing alternatives.

Occupational and Public Health and Safety

Highway Construction. Approximately 2 traffic-related fatalities could occur among workers and members of the public during the upgrading of Nevada highways for heavy-haul truck use. There would be no other common impacts for highway construction under any of the implementing alternatives. Section 6.3.3.2 describes impacts for the implementing alternatives. The construction of a midroute stopover for routes originating in Caliente would not add much to the impacts of highway construction discussed in Section 6.3.3.2.

Intermodal Transfer Station Construction. Impacts to workers from industrial hazards during the construction of an intermodal transfer station would be the same for all three possible locations. These impacts would be small (see Table 6-52). The analysis estimated impacts to workers in terms of total recordable cases of injury or illness, lost workday cases, and fatalities to workers. In addition, it estimated that there would be less than 1 (0.01) construction and construction workforce traffic-related fatality.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Section 6.3.3.2 discusses impacts for heavy-haul truck transportation and operations for each of the heavy-haul truck implementing alternatives. Common impacts for intermodal transfer station operations would include those to workers from industrial hazards and exposure to ionizing radiation (radiological impacts). DOE has determined that, because worker exposures to hazardous or toxic materials would be unlikely, workers at the station would incur no impacts from such materials. Table 6-53 lists potential impacts to workers from industrial hazards. In addition, there would be less than one (0.5) traffic-related fatality involving intermodal transfer station workers during operations.

Table 6-52. Health impacts to workers from industrial hazards during construction of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	4	2	0.01
Noninvolved[b]	0.3	0.1	0
Totals[c]	**4.3**	**2.1**	**0.01**

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Impacts are totals for 1.5 years.

Table 6-53. Health impacts to workers from industrial hazards during operation of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	69	37	0.1
Noninvolved[b]	3.1	1.0	0
Totals[c]	**72**	**38**	**0.1**

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Totals for 24 years of operations.

Intermodal transfer station workers would be exposed to direct radiation from the shipping casks the station would handle. Involved worker exposures would occur during both the inbound (to the proposed repository) and outbound (to the commercial and DOE sites) portions of the shipment campaign. The involved worker group would include as many as 20 personnel performing station operational tasks over a total shipment campaign of about 21,630 casks (10,815 inbound and 10,815 outbound). The analysis assumed that noninvolved workers would not be exposed to direct radiation during intermodal transfer station operations. Table 6-54 lists doses and radiological impacts to an individual worker and the involved worker population. The estimated doses are based on involved worker doses from Smith, Daling, and Faletti (1992, page 4.2).

Table 6-54. Doses and radiological impacts to involved workers from intermodal transfer station operations.[a]

Group	Dose	Latent cancer fatality
Maximum individual worker	12 rem[b]	0.005[c]
Involved worker population	260 person-rem	0.11[d]

a. Totals for 24 years of operations.
b. Assumes annual doses to intermodal transfer station workers would be limited to 0.5 rem per year.
c. The estimated probability of a latent cancer fatality in an exposed individual.
d. The estimated number of latent cancer fatalities in an exposed involved worker population.

Table 6-54 indicates that the involved group of workers could incur a collective dose of about 260 person-rem over the operating period of the intermodal transfer station. The analysis estimated that about 0.1 latent cancer fatality would occur in the exposed worker population. The maximum individual dose accumulated by these workers was assumed to be 500 millirem per year or 12 rem for a worker who worked at the facility for the 24-year operating period. This dose would result in a 0.005 probability of a latent cancer fatality (about a 1-in-200 chance). The assumed annual average dose to an involved worker is the administrative limit on occupational dose that DOE established for its facilities (DOE 1994c, Article 211). Because vehicles would not be loaded or unloaded at a midroute stopover (Caliente routes), workers at the stopover would receive only small radiation doses.

Incident-Free Transportation. Incident-free impacts of heavy-haul truck transportation in Nevada would be unique for each of the five Nevada heavy-haul truck transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.3.2. In addition, the incident-free impacts that would occur in Nevada from 2,600 legal-weight truck shipments, although common among the heavy-haul truck implementing alternatives, are reported along with the incident-free impacts for heavy-haul truck transportation in Section 6.3.3.2 for each heavy-haul truck implementing alternative.

Accidents. Accident risks and maximum reasonably foreseeable accidents for heavy-haul truck shipments of spent nuclear fuel and high-level radioactive waste would be the same among the Nevada heavy-haul truck transportation implementing alternatives, so this section discusses them.

Table 6-55 lists the accident risks from the transportation of spent nuclear fuel and high-level radioactive waste for the five Nevada heavy-haul truck transportation implementing alternatives. The data show that the risks, which are for 24 years of operations, are low for all five alternatives. These risks include those associated with transporting 2,600 legal-weight truck shipments from the commercial sites that do not have the capability to load rail casks. Small variations in the risk values, principally evident for a Sloan/Jean route, are in part a result of the risks associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area to a Sloan/Jean intermodal transfer station. The values that would apply for a Caliente-Chalk Mountain or Apex/Dry Lake route are lower because of a shorter route (Apex/Dry Lake), or a more remote and mid-length route (Caliente-Chalk Mountain).

Table 6-55. Health impacts[a] to the public from accidents for Nevada heavy-haul truck implementing alternatives.

Risk	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Apex/Dry Lake	Sloan/Jean
Radiological accident risk					
Dose-risk (person-rem)	0.29	0.26	0.72	0.67	4.1
LCF[b]	0.0001	0.0001	0.0004	0.0003	0.002
Traffic fatalities	0.73	0.42	0.54	0.31	0.33

a. Impacts are reported for 24 years of operations.
b. LCF = latent cancer fatality.

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. DOE evaluated the impacts of maximum reasonably foreseeable accident scenarios for national transportation (see Section 6.2).

Socioeconomics

DOE analyzed the socioeconomic impacts of Nevada heavy-haul truck transportation for impacts from expenditures to upgrade and maintain Nevada highways, operate heavy-haul trucks, construct and operate a midroute stopover for routes originating in Caliente, and construct and operate an intermodal transfer station.

Highway Construction. Socioeconomic impacts from upgrading highways in Nevada (including constructing a midroute stopover) would be transient, occurring over short periods. For the most part, the projected impacts of highway upgrade work would occur in Clark County, which the analysis assumed would be the home county for construction workforces. Section 6.3.3.2 discusses impacts to communities and counties along the five potential routes. The construction time and employment required to complete road upgrades would depend on the route.

Intermodal Transfer Station Construction. If a decision was made to construct an intermodal transfer station, DOE anticipates that preliminary architecture and engineering work would begin in 2007,

followed by the start of construction at the selected site in 2008. Construction would last about one and one-half years and would require 49 workers. For this analysis, DOE assumed that construction workers would probably come from Clark County.

The total increase in employment (direct and indirect) that would result from the project would peak in 2008 and would include about 130 workers. Population increases resulting from a net influx of new workers would peak in 2009 with about 70 additional residents. These employment and population increases, which would occur mostly in Clark County, would be small and temporary for the affected counties.

Increases in real disposable income from constructing an intermodal transfer station would peak in 2008 at between about $2.7 million and $3.1 million. The increase in Gross Regional Product would also peak in 2008 at between $7.5 million and $8.0 million. State and local government expenditures would peak in 2009 at about $200,000. These increases to real disposable income, Gross Regional Product, and government expenditures would be small for Clark County. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Highway Maintenance for Heavy-Haul Truck Operations. If DOE decided to use heavy-haul trucks, annual maintenance would be required after the completion of the highway upgrades. In addition, the routes would be resurfaced approximately every 8 years. Thus, highway expenditures for resurfacing a selected route would occur in approximately 2017, 2025, and 2033. The employment required for road maintenance would depend on the selected route. Section 6.3.3.2 discusses route-specific impacts.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The socioeconomic impacts of operating heavy-haul trucks (including operating a midroute stopover for routes originating in Caliente) and an intermodal transfer station largely would occur in the county in which the station was located. Section 6.3.3.2 discusses these impacts.

Noise

Highway and Intermodal Transfer Station Construction. Impacts would occur from construction noise associated with upgrading road surfaces, constructing a midroute stopover, and constructing an intermodal transfer station. The upgrades and construction would include the use of earth-moving equipment (bulldozers, graders, loaders, dump trucks) and asphalt-laying equipment. The potential for noise impacts from construction would depend on the presence of humans along the routes and near the intermodal transfer station location. These persons would live in communities and possibly individual residences. Noise impacts from road upgrades and general construction would be transient and would move with the construction or end when the construction ended. The impacts, therefore, would be temporary for any location along affected highways. Construction noise, which would not occur at night, would be discernible (45 dBA) at distances as far as about 2,000 meters (6,600 feet).

The American Indian Writers Subgroup (AIWS 1998, page 2-19) has identified noise generated along transportation routes as a concern because it may affect ceremonies and the solitude necessary for healing and praying. Areas or sites of interest to Native Americans have not been identified along these routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Heavy-haul trucks would be double-tractor vehicles that this analysis assumed would travel at speeds of 32 to 80 kilometers (20 to 50 miles) an hour. Noise levels probably would be greatest when loaded heavy-haul trucks were moving up grades at speeds as slow as 8 kilometers (5 miles) an hour. This would occur as the trucks approached the proposed repository site and on portions of the Caliente route (see Chapter 2, Section 2.1.3.3). At 48 kilometers (30 miles) an hour, the estimated noise from a single heavy-haul truck moving up a 5-percent grade would be 45 dBA at a distance of 630 meters (about 2,100 feet) from the road with no background

traffic. Elevated truck noise would not be a consideration on the Nevada Test Site, the Nellis Air Force Range, or the repository site. Transportation workers would use hearing protection as required by Occupational Safety and Health Administration regulations.

During operations, DOE would transport 11 shipments a week of spent nuclear fuel and high-level radioactive waste to the proposed repository and 11 empty casks from the repository. Because the heavy-haul trucks probably would travel individually, elevated noise would occur during the brief time when a vehicle passed through communities. There would be no nighttime noise because trucks of this size would be restricted to operating during daylight hours. Truck noise at a midroute stopover would be similar to noise along the adjacent route. Therefore, the potential for adverse noise impacts from heavy-haul trucks would be low.

Noise associated with operations at an intermodal transfer station would occur as it received shipments and transferred them from railcars to heavy-haul trucks for transport to the proposed repository site. However, the baseline noise level is already elevated because of existing rail line operations at the potential station locations. Additional sources of noise at a station would include transferring railcars from trains into the station, moving the railcars in the station, and receiving returning empty transportation casks. Railcars could come to the station at night, so there would be a potential for nighttime sources of noise. However, shipments in the station could be handled during daylight hours, minimizing the potential for noise impacts.

Other noise impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

Aesthetics

Highway and Intermodal Transfer Station Construction. There could be impacts on visual resources during these activities because of the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, and dust generation. However, this phase would be of limited duration (approximately 18 months for an intermodal transfer station and up to 30 months for highway improvements). Dust generation would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would not exceed the Bureau of Land Management Visual Resources Management guidelines (BLM 1986, all). If the route crosses Class II lands, more stringent management requirements would be necessary to retain the existing character of the landscape. However, the short duration of highway modification or construction activities, combined with the use of best management practices, would mitigate the impacts of activities, which could exceed the management requirements on any Class II lands.

Heavy-Haul Truck and Intermodal Transfer Station Operations. As many as 22 shipments would leave or arrive at the intermodal transfer station each week. Visual impacts would result from the presence of the station, increased worker activity in the area, the arrival and departure of trains, loading and unloading operations, and the arrival and departure of heavy-haul trucks. Some noise would occur from activities at the station, which could draw attention to it. These impacts would not exceed Class III objectives, which require only the partial retention of the existing character of the landscape.

Other aesthetic impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

Utilities, Energy, and Materials

Highway Construction. The amounts of utilities, energy, and materials needed would depend on the amount of upgrading to be done, which would be specific to each route. The amount of utilities, energy, and materials for each route is given in the following sections. All of the required amounts are much less than current use rates in Nevada. For example, fossil-fuel consumption in Nevada was about 3.8 billion

liters in 1996 and none of the routes would require more than 0.5 percent of the annual consumption (BTS 1999a, Table MF-21).

Intermodal Transfer Station Construction. Intermodal transfer station design would be the same for any of the three sites and would include a small railyard with several sidings, a 180-metric-ton (200-ton) bridge crane, two steel prefabricated buildings (one for administration and one for maintenance), and a large paved area for heavy-haul truck parking and maneuvering. The basic facility would be a light industrial site with moderate utility requirements. During construction the electrical requirements would be supplied by portable generating equipment. Table 6-56 lists the materials that would be consumed during construction. The quantities of concrete, asphalt, and steel listed in the table are not substantial in comparison to annual use rates and would not affect the regional supply system. For example, the concrete required for an intermodal transfer station would be less than 1 percent of the concrete used in Nevada in 1998 (Sherwood 1998, all). Similarly, the demand for electricity and fossil fuel during construction would not be great. The construction of a midroute stopover for heavy-haul trucks (routes originating in Caliente) is accounted for in the specific route data included in the following sections.

Table 6-56. Construction utilities, energy, and materials for an intermodal transfer station over 1.5 years.

Electrical demand (kilowatts)	Fossil fuel (liters)[a]	Concrete (thousand metric tons)[b]	Asphalt (thousand metric tons)	Steel (thousand metric tons)
Onsite generation	Small	7.9	18	1.4

a. To convert liters to gallons, multiply by 0.26418.

b. To convert metric tons to tons, multiply by 1.1023.

Highway Maintenance for Heavy-Haul Truck Operations. Highways used by heavy-haul trucks would be maintained annually and resurfaced, on average, every 8 years. The amounts of utilities, energy, and materials for the annual and 8-year maintenance activities would be less than the initial amounts for upgrading the highways.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The current estimate of electrical demand during the operation of an intermodal transfer station would be 165 kilowatts (TRW 1999d, Heavy-Haul Truck Files, Item 11). This would include 30 kilowatts for lighting, 50 kilowatts for each of the two buildings, 5 kilowatts for the guard station, and 30 kilowatts for the crane. The actual rate would be substantially less than peak capacity because operations would be intermittent. Only small amounts of fossil fuel would be used at an intermodal transfer station. Chapter 10 discusses fossil-fuel use for heavy-haul truck operations.

Other impacts on utilities, energy, and materials would differ among the implementing alternatives, as described in Section 6.3.3.2.

Waste Management

Highway Construction. Most wastes from upgrading highways, including constructing a midroute stopover, would be nonhazardous industrial or construction wastes that a contractor would dispose of in permitted industrial landfills or a permitted construction debris landfill, respectively. Hazardous waste such as lubricants and solvents or other hazardous materials would be shipped to a permitted hazardous waste treatment and disposal facility for appropriate disposition. In addition to disposition, much of the residual material from construction activities would be saved for reuse or recycled. Excess excavated materials such as soil and rock would be placed in spoil areas created for that purpose. A commercial vendor would provide portable restroom facilities and would manage the sanitary sewage.

Intermodal Transfer Station Construction. Construction would require traditional materials such as steel, lumber, and concrete that would result in debris that would require disposal or recycling. Excess

construction materials would be salvaged. Construction debris would be disposed of in a local construction debris landfill. In addition, construction could require paints and resins that could become a hazardous waste if discarded. Hazardous waste would be shipped to a permitted treatment and disposal facility. A commercial vendor would provide portable restroom facilities and manage sanitary sewage. Waste quantities from construction would be about the same for all sites. The small impacts from disposing of the construction debris, hazardous waste, and sanitary sewage would be consistent for all station locations.

Highway Maintenance for Heavy-Haul Truck Operations. Periodic maintenance of highways and resurfacing every 8 years would generate construction wastes such as those discussed above for the initial highway improvements. Asphalt would be recycled.

Heavy-Haul Truck Operations. Heavy-haul truck operations along any of the five routes, including the operation of a midroute stopover for routes originating in Caliente, would result in wastes from vehicle maintenance and operation. These would include waste lubricants; solvents, paints, and other hazardous materials; sanitary waste; and industrial wastes typical of trucking company operations. Management and disposition of the wastes from operations would comply with applicable environmental and occupational and public safety regulations.

Intermodal Transfer Station Operations. Operations, regardless of the location, would generate (1) sanitary solid waste such as waste paper from office and personnel activities, (2) a small amount of hazardous waste from maintenance activities, and (3) potentially a small amount of low-level radioactive waste such as the smear wipes for radiological surveys of shipping casks and vehicles. In addition, the intermodal transfer station would generate sanitary sewage that DOE would dispose of in an onsite septic system or through connection to a municipal sewage facility.

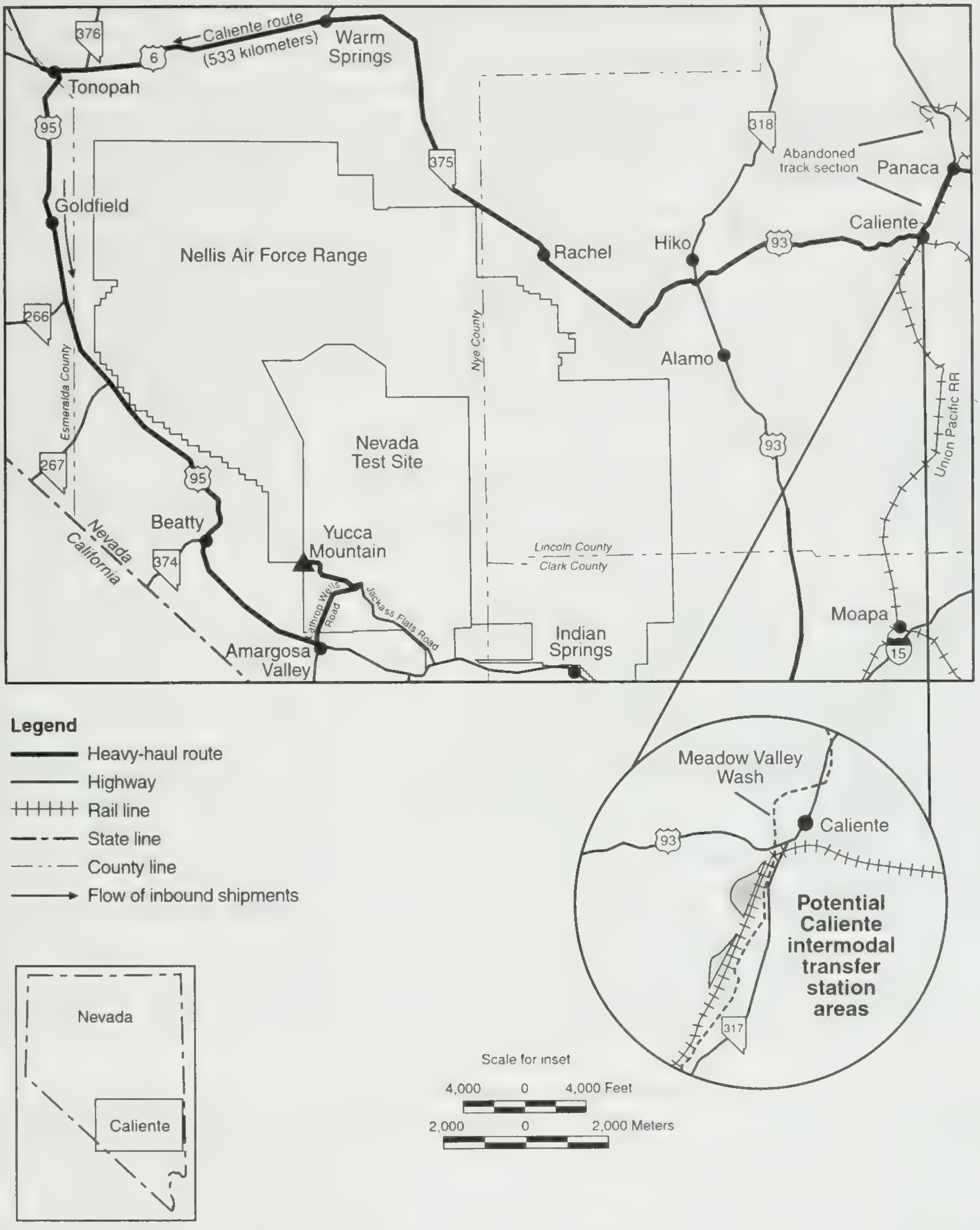
The intermodal transfer station operator would dispose of sanitary solid waste in a local permitted landfill with available capacity. Hazardous and low-level radioactive waste, if any, would be shipped to treatment and disposal facilities with appropriate permits. The small quantities would have very little impact to the treatment and disposal facilities. Treatment and disposal capacity for hazardous waste would be above the expected demand until 2013 (EPA 1996b, pages 32, 33, 36, 46, 47, and 50). Disposal capacity for a broad range of low-level radioactive wastes would be available at two currently licensed facilities, and three additional disposal facilities are under license review (NRC 1997a, section on U.S. Low-Level Radioactive Waste Disposal).

There are no waste management impacts unique to any of the heavy-haul truck implementing alternatives.

6.3.3.2 Specific Impacts from Nevada Heavy-Haul Truck Implementing Alternatives

6.3.3.2.1 *Caliente Route Implementing Alternative*

The Caliente route (Figure 6-18) would be approximately 533 kilometers (331 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the intermodal transfer station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. 6. The trucks would travel on U.S. 6 to the intersection with U.S. 95 in Tonopah. The trucks would travel into Beatty on U.S. 95 where an alternative truck route would be built because an existing intersection is too constricted to allow a turn. Heavy-haul vehicles would then travel south on U.S. 95 to the Lathrop Wells Road exit, which would access the Yucca Mountain site.



Potential heavy-haul routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DOE (1998g, all).

Figure 6-18. Caliente heavy-haul truck route.

Because of the estimated travel time associated with the Caliente route and the restrictions on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable these vehicles to park overnight. This parking area would be near U.S. 6 between Warm Springs and Tonopah.

The Caliente siting areas for an intermodal transfer station are south of the City of Caliente in the Meadow Valley Wash area. DOE has identified two areas along the west side of the canyon, with a combined area of 740,000 square meters (180 acres). Areas along the east side of the canyon would not be used to avoid disrupting Meadow Valley Wash and because of poor access to the Union Pacific rail line.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

This section describes land-use impacts that could occur from the construction and operation of a Caliente intermodal transfer station and upgrade of highways and heavy-haul truck operation over the Caliente route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated route.

With the exception of a small portion of the most northern part of the site area for an intermodal transfer station, the area is on patented land owned by the City of Caliente. The remaining part of the northern site is administered by the Bureau of Land Management. The northern site also includes an existing wastewater treatment plant (TRW 1999f, page 21).

Construction. There would be no unique land-use impacts for an intermodal transfer station in Caliente, Nevada. Land-use impacts that would be common to all locations are discussed in Section 6.3.3.1.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 0.04 square kilometer (10 acres) of land near Beatty, Nevada, would be acquired to construct approximately 2 kilometers (1.2 miles) of new highway. This section of highway would be needed to avoid conflicts between the requirement of wide turning areas for heavy-haul trucks and existing land uses in Beatty where U.S. 95 makes a 90-degree turn. In addition, approximately 0.04 square kilometer (10 acres) of land in the vicinity of Tonopah would be acquired for a midroute stopping area for heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente route for heavy-haul trucks other than those described in Section 6.3.3.1.

Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and heavy-haul truck operations over the Caliente route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that are unique to the Caliente route.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed apply to surface water along the Caliente route.

Groundwater

Construction. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente route would require about 126,000 cubic meters (100 acre-feet) (LeFever 1998b, all) of water which, for planning purposes, was assumed to come from 16 wells.

The average amount of water withdrawn from each well would be about 7,900 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-57 summarizes the status of the hydrographic areas associated with the Caliente route. It also identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

Table 6-57. Hydrographic areas along Caliente route.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
19	8	45

The withdrawal of 7,900 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-57, about 45 percent of the route's length would be in areas with Designated Groundwater Basins, where the Nevada State Engineer's office carefully watches the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Requests for water appropriations under this action would be for minor amounts and for a short-term construction action, which should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck to construction sites (about 7,000 truckloads), or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

Biological Resources

Section 6.3.3.1 discusses the impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and associated routes. This section discusses the construction- and operations-related impacts that are unique to the Caliente intermodal station and route.

Construction. Potential Caliente intermodal transfer station siting locations include two areas along the west side of the Meadow Valley Wash canyon. The land cover types are agriculture and salt desert scrub (TRW 1999k, page 3-30). The construction site would disturb approximately 0.2 square kilometer (50 acres). No special status species occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by the Bureau of Land Management—the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker—occur in the adjacent Meadow

Valley Wash (TRW 1999k, page 3-30). The construction of an intermodal transfer station could affect these fish by increasing the sediment load in the wash during construction. There is no designated game habitat at the proposed location for the intermodal transfer station, but the adjacent Meadow Valley Wash is classified as important habitat for water fowl and Gambel's quail (TRW 1999k, page 3-30). Impacts to this habitat would be small.

Moist areas in the proposed location and the adjacent perennial stream and riparian habitat along Meadow Valley Wash could be classified as jurisdictional wetlands or other waters of the United States, although no formal wetlands delineation of the area has been conducted. If this site was selected, DOE would delineate the boundaries of any jurisdictional wetlands, develop a plan to mitigate impacts, and consult with the U.S. Army Corps of Engineers regarding the need to obtain a regional or individual permit under Section 404 of the Clean Water Act.

The predominant land cover types along the Caliente route are salt desert scrub, sagebrush, and creosote-bursage (TRW 1999k, page 3-30). The regional area for each vegetation type is extensive (Utah State University 1996, GAP data). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way, and have been previously degraded by human activities, impacts would be small.

Three threatened or endangered species occur along the Caliente route (TRW 1999k, page 3-30). The desert tortoise occurs along the southern part of the route along U.S. 95 from Beatty to Yucca Mountain. Construction activities could kill or injure some tortoises; however, their abundance is low in this area (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411) so losses would be small. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (50 CFR 17.95). The outflow of the spring comes within about 10 meters (33 feet) of State Route 375 near its intersection with State Route 318 near U.S. 93 (TRW 1999k, page 3-31). The construction or widening of the road would be unlikely to affect this species, because construction activities would avoid the spring outflow channel and because no sediment would enter the stream. An introduced population of the threatened Railroad Valley springfish occurs in Warm Springs (FWS 1996, page 20), the outflow of which crosses U.S. 6. If improvements to the highway in the vicinity of the Warm Springs outflow were necessary, there could be temporary adverse impacts to this introduced population due to habitat disturbance and siltation. Six other special status species occur along this route (TRW 1999k, pages 3-30 and 3-31) but, because construction activities would be limited to the road and adjacent areas and care would be taken to ensure no sediments would enter streams, species should not be affected.

This route would cross eight areas designated as game habitat (TRW 1999k, page 3-31). The amount of habitat in these areas would be reduced slightly due to construction activities alongside existing roads. Game animals in these areas during construction could be disturbed.

Nineteen springs occur near this route (TRW 1999k, page 3-31). Areas around these springs may be jurisdictional wetlands or waters of the United States. However, no formal delineation has occurred. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual or regional permits, as appropriate.

Impacts on soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along the route. Trucks probably would kill

individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente route. Impacts of the associated intermodal transfer station are the same for each heavy-haul truck implementing alternative and are in Section 6.3.3.1.

Construction. Industrial safety impacts on workers from the upgrade of highways and use of the Caliente route would be small (see Table 6-58). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities due to commuting workers and transporting construction materials and equipment. Table 6-59 lists the estimated fatalities from construction vehicle and commuter traffic.

Table 6-58. Impacts to workers from industrial hazards during the Caliente route construction upgrades.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	28	290
Lost workday cases	13	160
Fatalities	0.2	0.5
Noninvolved workers[d]		
Total recordable cases	5	13
Lost workday cases	2	7
Fatalities	0.01	0.01
Totals[e]		
Total recordable cases	33	300
Lost workday cases	15	170
Fatalities	0.2	0.5

a. Impacts are totals for about 2 years.
b. Includes impacts from periodic resurfacing and maintenance; impacts are totals for 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-60 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente route. These impacts include transportation along the highway route as well as transportation along railways in Nevada to the Caliente intermodal transfer station. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

This section describes socioeconomic impacts that would occur from upgrading and using highways on the Caliente route and building an intermodal transfer station for heavy-haul truck transportation. It includes impacts from the operation of an intermodal transfer station at the Caliente site.

Construction. Socioeconomic impacts from upgrading highways for the Caliente route and building an intermodal transfer station would be transient, occurring over short periods and spread among the communities and counties along a route. Employment for route upgrades and intermodal transfer station construction would be about 250 workers. Upgrading the Caliente route would cost about $120 million (1998 dollars) and would require 36 months to complete. Constructing an intermodal transfer station would cost $24 million (1998 dollars) and require 1.5 years.

At its peak, increased employment for both construction workers (direct workers) and other workers who would be employed either because of highway upgrade and intermodal transfer station projects or as a result of the economic activity generated by the project (indirect workers) would be about 1,000. The change in employment for Clark, Nye, and the other Nevada counties except Lincoln County would be less than 1 percent of their employment bases. For Lincoln County, the increase in employment would be

Table 6-59. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	180,000,000	3.1	0.013
Commuting workers	54,000,000	0.5	0.004
Subtotals[c]	*234,000,000*	*3.6*	*0.017*
Operations[d]			
Commuting workers	198,000,000	2.0	0.014
Totals	***432,000,000***	***5.6***	***0.031***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impact totals are for about 2 years.
c. Totals might differ from sums due to rounding.
d. Impact totals are for 24 years.

Table 6-60. Health impacts from incident-free Nevada transportation for the Caliente route implementing alternative.[a]

Category	Legal-weight truck shipments[b]	Rail and heavy-haul truck shipments[c]	Totals[d]
Involved workers			
Collective dose (person-rem)	220	560	780
Estimated latent cancer fatalities	0.09	0.22	0.31
Public			
Collective dose (person-rem)	270	1,800	2,100
Estimated latent cancer fatalities	0.13	0.88	1.0
Estimated vehicle emission-related fatalities	0.00014	0.0052	0.0053

a. Impacts are totals for 24 years (2010 to 2033).
b. Impacts of 2,600 legal-weight truck shipments from nine commercial sites.
c. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
d. Totals might differ from sums of values due to rounding.

as much as 2.3 percent of the county's employment base. The increase in employment in Lincoln County would be a moderate impact. However, it would be within historic short-term changes in employment for the county.

As a result of increased employment, population would be affected. The projected increases in population would reach a peak in 2009. During that year, the cumulative increase in population would be about 700. Population changes for Clark, Lincoln, or Nye County that would arise from increased employment would be less than 1 percent above the baseline. Thus, employment and population impacts arising from highway upgrade and intermodal transfer station construction projects would be small in comparison to existing employment and populations in the counties.

The increase in real disposable income of people in the affected counties would reach a peak in 2008 at $25.2 million. Gross Regional Product would peak in 2008 at $42.0 million. Increased State and local government expenditures resulting from highway upgrade and intermodal transfer station construction projects would reach their peak in 2009 at $2.0 million. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Changes to real disposable income and government expenditures would be small —less than 1 percent for Clark, Lincoln, Nye, and the other Nevada counties — as would changes to Gross Regional Product in Clark, Nye, and other counties. The change in Gross Regional Product in Lincoln County would be

moderate, amounting to about 1.5 percent of the baseline but remaining within historic short-term changes in the county.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and last until 2033. An operations workforce of about 26 would be required for the intermodal transfer station. For the national mostly rail transportation scenario, the station would operate throughout the year. The workforce for heavy-haul truck operations over a Caliente route, including shipment escorts, would be about 120 workers. The analysis assumed that operations workers would reside in Clark, Lincoln, and Nye Counties.

Employment would be likely to remain relatively level throughout operations. Operations employment (direct and indirect) would average about 240 workers. About 90 of these workers would be in Lincoln County. The impact on population would be about 480 additional residents, with about 125 of these in Lincoln County. Employment and population increases for Lincoln County, which would experience the largest changes as a percentage of the baseline would be about 1.9 to 5.8 percent. These employment and population impacts during operations would be moderate in comparison to the existing employment and population levels for the county and would be within the range of historic changes in the county.

Real disposable income from operating an intermodal transfer station in Caliente and operating heavy-haul trucks based in Caliente would rise throughout operations, starting at $2.6 million in 2010 and rising to $11.7 million in 2033. Gross Regional Product would also rise during operations starting at $4.4 million in 2010 and increasing to $13.7 million in 2033. Annual State and local government expenditures would increase from $340,000 in 2010 to $2.6 million in 2033. Increases to real disposable income, Gross Regional Product, and government expenditures would be moderate in Lincoln County. Changes in real disposable income and government expenditures for the county would be about 2.7 and 1.7 percent, respectively. The projected change in Gross Regional Product for Lincoln County would be 4.0 percent; this would be within historic short-term changes for the county.

Because of the periodic need to resurface highways used by the heavy-haul trucks, employment would increase in the years these projects occurred. During those years, employment (direct and indirect) in the region would increase by about 250 for a Caliente route. Overall, employment changes from periodic (every 8 years) highway resurfacing projects would be less than 1 percent in Clark, Nye, and Lincoln Counties for the route. The impacts of the increases would be small.

Population increases would follow the increases in employment for highway resurfacing projects. Overall, the short-term increase in population in Nevada counties would be about 120 for a Caliente route. As a consequence, impacts to employment and population in affected counties in Nevada would be small and transient for highway resurfacing projects.

Noise

Section 6.3.3.1 discusses the noise impacts common to all heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Construction. The Caliente intermodal transfer station would border a wastewater treatment facility; there are no residences near the site. As a consequence, the potential for noise impacts from construction and operations would be nonexistent at this location.

Operations. For the Caliente route, the small rural communities of Amargosa Valley (at Lathrop Wells Road exit), Rachel, and Crystal Springs, and the Towns of Beatty, Goldfield, Tonopah, and Caliente would all fall within the 2,000-meter (6,560-foot) region of influence for construction noise. Noise

impacts resulting from shipments along the Caliente route, based on community size and the number of affected communities, would be unlikely. Shipments would pass four established towns and three rural areas during transit to the Yucca Mountain site.

Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Construction. The construction of the Caliente intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-61 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-61. Utilities, energy, and materials required for upgrades along the Caliente route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente	533	13.0	220	1.4	1.8	49.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and material needs for operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.2 *Caliente-Chalk Mountain Route Implementing Alternative*

The Caliente-Chalk Mountain route (Figure 6-19) would be approximately 282 kilometers (175 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, then on State Route 375 to the Town of Rachel. Next they would head south on Valley Road through the Nellis Air Force Range past Chalk Mountain to the Groom Pass Gate to the Nevada Test Site.

Because of the estimated travel time associated with the Caliente-Chalk Mountain route and anticipated limits on travel on the Nellis Air Force Range, DOE would construct a parking area along the route near the northern boundary of the Nellis Air Force Range to enable these vehicles to park overnight.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

The following sections address impacts that would occur to land use; biological resources and soils; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to air quality, cultural resources, aesthetics, and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

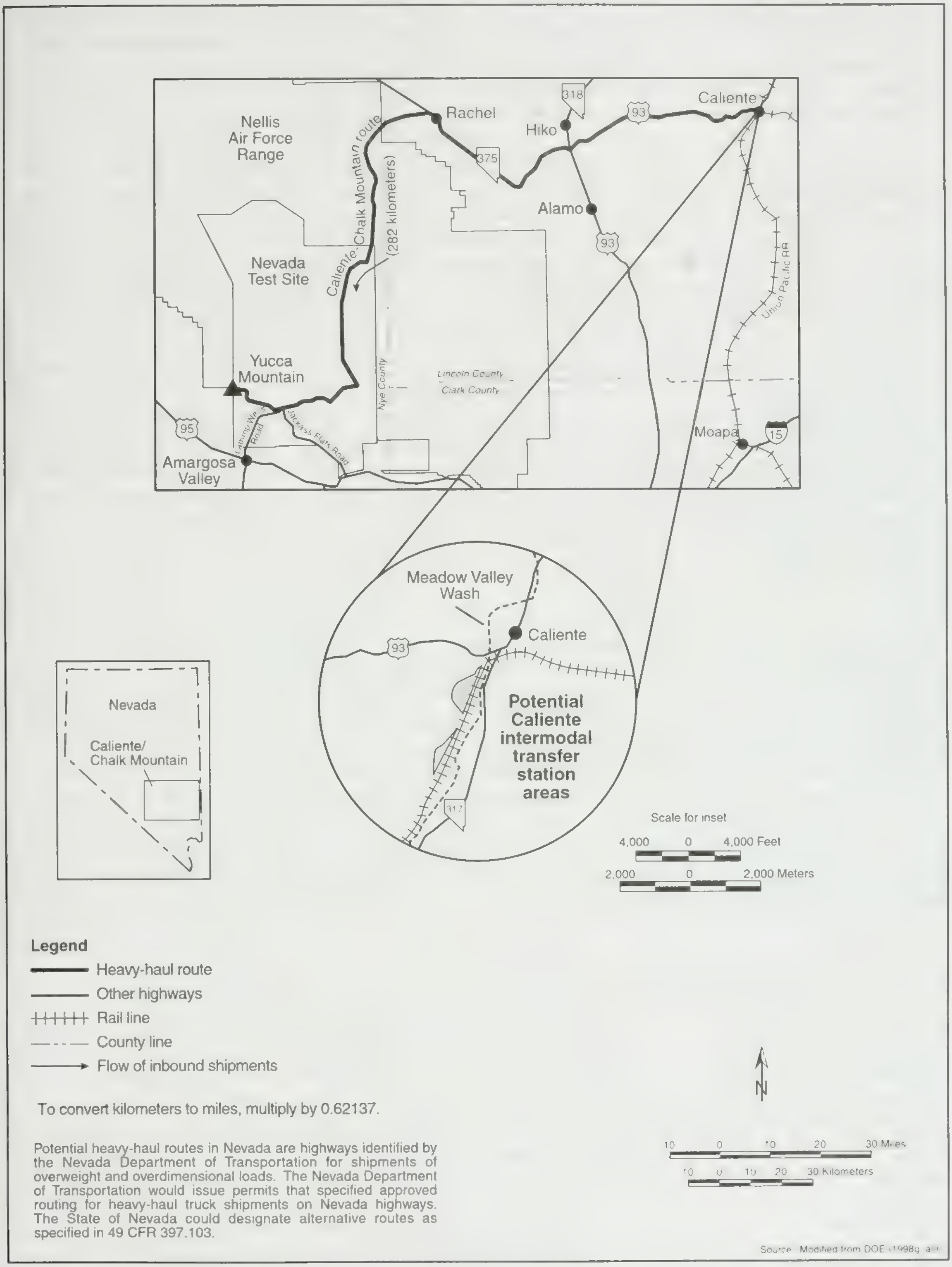


Figure 6-19. Caliente-Chalk Mountain heavy-haul truck route.

Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Caliente intermodal transfer station, upgrades of highways, and heavy-haul truck operations over the Caliente-Chalk Mountain route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and the associated route.

Construction. Section 6.3.3.2.1 discusses Caliente intermodal transfer station impacts in relation to the current use of the land. Section 6.3.3.1 describes impacts on land use from upgrading highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 0.04 square kilometer (10 acres) of land in the vicinity of the northern boundary of the Nellis Air Force Range would be acquired for a midroute stopping area for heavy-haul trucks.

The Caliente-Chalk Mountain route would involve land controlled by the Nellis Air Force Range, which, according to the Air Force, would affect Air Force operations. Because Public Law 99-606 withdrew and reserved the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through the Range before DOE could build and operate this line. The Air Force has identified national security issues regarding a Caliente-Chalk Mountain route, citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE has stated that it is acutely conscious of the security issues such a route would present and, because of the concerns expressed by the Air Force, regards the route as a "non-preferred alternative."

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente-Chalk Mountain route other than those described above and in Section 6.3.3.1.

Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so that they could accommodate daily use by heavy-haul trucks. This section discusses these potential environmental impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente-Chalk Mountain route. Section 6.3.3.1 discusses the hydrological impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente-Chalk Mountain route.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways.

Groundwater

Construction. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. Upgrades to the Caliente-Chalk Mountain route would require about 75,000 cubic meters (60 acre-feet) of water (LeFever 1998b, all) that the analysis assumed would come from five wells.

The average amount of water withdrawn from each well would be about 15,000 cubic meters (12 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies hydrographic areas over which the Caliente-Chalk Mountain route would pass, their perennial yields, and whether the State considers each a Designated Groundwater

Table 6-62. Hydrographic areas along Caliente-Chalk Mountain route.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
10	2	20

Basin. Table 6-62 summarizes the status of the hydrographic areas associated with the Caliente-Chalk Mountain heavy-haul route. It also identifies the approximate percentage of the route that would pass over Designated Groundwater Basins.

The withdrawal of 15,000 cubic meters (12 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente-Chalk Mountain route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-62, about 20 percent of the route's length would be in areas with Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (4,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente-Chalk Mountain route.

Construction. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station siting locations and impacts to biological resources from station construction.

The predominant land cover types along the Caliente-Chalk Mountain route are salt desert scrub, blackbrush, sagebrush, and creosote-bursage (TRW 1999k, page 3-31). The regional area for each vegetation type is extensive (Utah State University 1996, GAP data). Because areas disturbed by highway upgrade activities would be in or adjacent to existing rights-of-way, and because these areas have been previously degraded by human activities, impacts would be small.

Two threatened or endangered species occur along the route (TRW 1999k, page 3-32). The desert tortoise occurs along the southern part of the route from the northern end of Frenchman Flat to Yucca Mountain. Construction activities could kill or injure desert tortoises; however, their abundance is low in this area (Rautenstrauch and O'Farrell 1998, pages 407 to 411), so losses would be few. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (FWS 1998, page 16), which is about 10 meters (33 feet) south of State Route 375 near its intersection with Nevada 318 near U.S. 93. Construction or widening of the road is not likely to affect this species because construction activities would avoid the spring outflow channel and no sediment would enter the stream, which is critical habitat for this fish (50 CFR 17.95). Three other special status species occur along this route, but because construction activities would occur along existing roads, they should not be affected. Standard construction practices would be used to reduce erosion and runoff.

This route would cross six areas designated as game habitat (TRW 1999k, page 3-32). The amount of habitat in these areas would be reduced very slightly due to construction activities along existing roads. Game animals could be disturbed if they were in these areas during construction.

Three springs or riparian areas occur near this route (TRW 1999k, page 3-32). These springs and riparian areas may be jurisdictional wetlands or other waters of the United States; however, no formal delineation has occurred. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente-Chalk Mountain route. Impacts of the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.1.

Construction. Industrial safety impacts to workers from upgrading highways for the Caliente-Chalk Mountain route would be small (Table 6-63). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-64 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-63. Impacts to workers from industrial hazards from upgrading highways along the Caliente-Chalk Mountain route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	15	290
Lost workday cases	7	160
Fatalities	0.1	0.5
Noninvolved workers		
Total recordable cases	3	13
Lost workday cases	1	7
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	18	300
Lost workday cases	8	170
Fatalities	0.1	0.5

a. Impacts are totals over about 2 years.
b. Includes impacts from periodic maintenance and resurfacing. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-65 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente-Chalk Mountain route. These impacts include transportation along the route and along railways in Nevada leading to an intermodal transfer station. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

This section describes socioeconomic impacts that would occur from upgrading and using highways of the Caliente-Chalk Mountain route and building an intermodal transfer station for heavy-haul truck transportation. It includes the impacts from the operation of an intermodal transfer station at Caliente.

Table 6-64. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente-Chalk Mountain route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	45,000,000	0.8	0.0032
Commuting workers	30,000,000	0.3	0.0021
Subtotals	*75,000,000*	*1.1*	*0.0053*
Operations[c]			
Commuting workers	180,000,000	1.8	0.013
Totals[d]	***260,000,000***	***2.9***	***0.018***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 2 years.
c. Impacts are totals over about 24 years.
d. Totals might differ from sums due to rounding.

Table 6-65. Impacts from incident-free transportation for the Caliente-Chalk Mountain heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	220	490	710
Estimated latent cancer fatalities	0.09	0.20	0.29
Public			
Collective dose (person-rem)	270	970	1,200
Estimated latent cancer fatalities	0.13	0.49	0.62
Estimated vehicle emission-related fatalities	0.00014	0.0032	0.0033

a. Impacts are totals for 24 years (2010 to 2033).
b. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
c. Totals might differ from sums due to rounding.

Construction. Socioeconomic impacts from upgrading highways for the Caliente-Chalk Mountain route and building an intermodal transfer station would be transient, occurring over short periods and spread among the communities and counties along a route. Employment for route upgrades and intermodal transfer station construction would be about 240 workers. Upgrading this route would cost about $63 million (1998 dollars) and would require 26 months to complete. Constructing an intermodal transfer station would cost $24 million (1998 dollars) and require 1.5 years.

At its peak, increased employment for both construction workers (direct workers) and other workers who would be employed either because of highway upgrades and intermodal transfer station projects or as a result of the economic activity generated by the project (indirect workers) would be about 830. The change in employment for Clark, Nye, and the other Nevada counties except Lincoln County would be less than 1 percent of the counties' employment bases. For Lincoln County, the increase in employment would be as much as 2.6 percent of the employment base. The increase in employment in Lincoln County would be a moderate impact; however, it would be within historic short-term changes for the county.

As a result of increased employment, population would also be affected. Projected increases in population would reach a peak in 2009. During that year, the cumulative increase in population would be about 480. Population changes for Clark, Lincoln, or Nye County that would arise from increased employment would be less than 1 percent above the baseline. Thus, for the Caliente-Chalk Mountain route, employment and population impacts arising from highway upgrade and intermodal transfer station construction projects would be small in comparison to existing employment and populations in the counties.

The increase in real disposable income in the affected counties would peak at about $19.6 million in 2008. Gross Regional Product would peak in 2008 at $35.3 million. Increased State and local government expenditures resulting from highway improvement projects would reach their peak in 2009 at $1.3 million. Changes to government expenditures and real disposable income would be small—less than 1 percent for Clark, Lincoln, and Nye Counties. Changes to Gross Regional Product in the counties in Nevada except Lincoln County would also be small—less than 1 percent. Changes in Lincoln County of about 1.8 percent for Gross Regional Product would be moderate but within the range of historic short-term changes for the county. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and last until 2033. An operations workforce of 26 would be required for the intermodal transfer station. For the national mostly rail transportation scenario, the station would operate throughout the year. The workforce for heavy-haul truck operations over a Caliente-Chalk Mountain route, including shipment escorts, would be 110 workers. The analysis assumed that operations workers would reside in Lincoln County.

Employment would be likely to remain relatively level throughout operations. Operations employment (direct and indirect) would average about 230 workers. Under the assumptions of the analysis, about 135 workers would be employed in Lincoln County. The impact on population would be about 425 additional residents. Employment and population increases for Lincoln County, which would experience the largest changes, would be about 4.0 to 5.0 percent of the baseline. These employment and population impacts during operations would be moderate in comparison to the existing employment and population levels for the county and would be within the range of historic changes in the county.

Real disposable income from operating an intermodal transfer station in Caliente and operating heavy-haul trucks from it would rise throughout operations, starting at $2.4 million in 2010 and increasing to $10.5 million in 2033. Gross Regional Product would also rise during operations, starting at 4.3 million in 2010 and increasing to $12.9 million in 2033. Annual State and local government expenditures would increase from $350,000 in 2010 to $2.7 million in 2033. Increases to real disposable income, Gross Regional Product, and government expenditures would be moderate in Lincoln Country for the Caliente-Chalk Mountain route. Changes in real disposable income and government expenditure for the county would be about 3.2 and 2.4 percent, respectively. The projected change in Gross Regional Product for the county would be 5.8 percent.

Because of the periodic need to resurface the highways used by the heavy-haul trucks, employment would increase in the years during which these projects occurred. During those years, employment (direct and indirect) in the region would increase by about 130 for a Caliente-Chalk Mountain route. Overall, employment changes from periodic (every 8 years) highway-resurfacing projects would be less than 1 percent in Clark, Nye, Lincoln, and other Nevada counties for the route. The impact of these increases would be small.

Population increases would follow the increases in employment for highway resurfacing projects. Overall the short-term increase in population in Nevada counties would be about 320 for a Caliente-Chalk Mountain route. As a consequence, impacts to employment and population in affected counties in Nevada would be small and transient for highway resurfacing projects.

Noise

Section 6.3.3.1 discusses the noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente-Chalk Mountain heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1. A large portion of the route would be inside the boundaries of the Nevada Test Site and the Nellis Air Force Range. The small rural communities of Crystal Spring and Rachel and the Town of Caliente would be within the 2,000-meter (6,560-foot) region of influence for construction noise.

Noise impacts resulting from shipments along the Caliente-Chalk Mountain route, based on community size and the number of affected communities, would be unlikely. The route passes one established town and two rural areas during transit to the Yucca Mountain site.

Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Caliente-Chalk Mountain heavy-haul truck implementing alternative.

Construction. The construction of the Caliente intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-66 lists the estimated quantities of primary materials for the upgrade of highways for the Caliente-Chalk Mountain route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-66. Utilities, energy, and materials required for upgrades along the Caliente-Chalk Mountain route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Chalk Mountain	282	4.7	77	0.41	0.5	14.1

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitment of resources.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

6.3.3.2.3 *Caliente-Las Vegas Route Implementing Alternative*

The Caliente-Las Vegas route (Figure 6-20) would be approximately 377 kilometers (234 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15 northeast of Las Vegas. The trucks would then travel south on I-15 to the exit for the proposed Las Vegas Beltway, and would travel west on the beltway. They would exit the beltway to U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

Because of the estimated travel time associated with the Caliente-Las Vegas route and the restrictions on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable

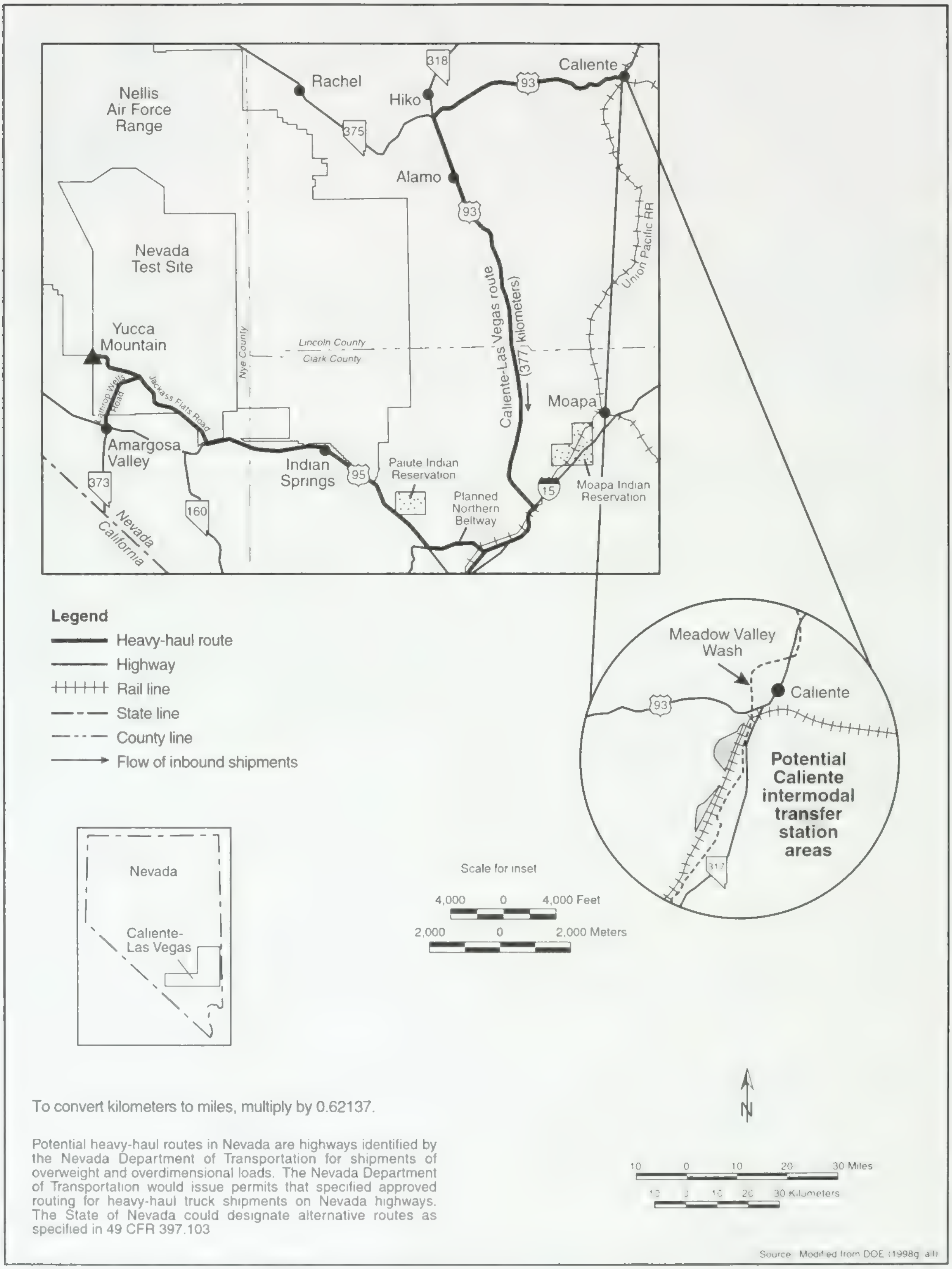


Figure 6-20. Caliente-Las Vegas heavy-haul truck route.

these vehicles to park overnight. This parking area would be near the U.S. 93 and I-15 intersection at Apex.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated truck route.

Construction. Section 6.3.3.2.1 discusses the Caliente intermodal station site area and impacts related to the current use of the land. Section 6.3.3.1.1 discusses the impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 0.04 square kilometer (10 acres) of land in the vicinity of Apex northeast of Las Vegas would be acquired for a midroute stopping area for heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or use of the Caliente-Las Vegas route other than those described in Section 6.3.3.1.

Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station and upgrades and heavy-haul truck operation along the Caliente-Las Vegas route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10} and $PM_{2.5}$).

Construction. Section 6.3.3.1 discusses air quality impacts for the construction of the Caliente intermodal transfer station, which would be a result of emissions from construction equipment and fugitive dust from earth excavation and construction vehicle traffic.

Section 6.3.3.1 also discusses air quality impacts likely to occur from upgrades of the Caliente-Las Vegas route for heavy-haul truck transport. These impacts would be a result of emissions from construction equipment and fugitive dust from earth excavation and construction vehicle traffic. Construction equipment design and controls would ensure that emissions did not exceed ambient air quality standards. Most of the road upgrades would occur in areas that are in attainment for all criteria pollutants. However, portions of the upgrades along the Caliente-Las Vegas route would occur in the Las Vegas Valley airshed, which is in nonattainment for carbon monoxide and PM_{10} (FHWA 1996, pages 3-53 and 3-54).

Operations. Section 6.3.3.1 discusses air quality impacts associated with the operation of the Caliente intermodal transfer station and from emissions of heavy-haul trucks. The Caliente-Las Vegas route would involve heavy-haul trucks passing through the Las Vegas Valley airshed. The air quality impacts to this airshed from the operation of four or five trucks a day would be very small in comparison to the amount of pollutants emitted by automobile travel and other commercial vehicles in the basin.

Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente-Las Vegas route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente-Las Vegas heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed would apply to surface water along the Caliente-Las Vegas route.

Groundwater

Construction. Section 6.3.3.1 discusses impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente-Las Vegas route would require about 54,000 cubic meters (44 acre-feet) of water (LeFever 1998b, all) that the analysis assumed would come from seven wells.

The average amount of water withdrawn from each well would be about 7,700 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente-Las Vegas route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-67 summarizes the status of the hydrographic areas associated with the Caliente-Las Vegas route and identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

Table 6-67. Hydrographic areas along Caliente-Las Vegas route.

	Designated Groundwater Basins	
Hydrographic areas crossed	Number	Percent corridor length represented
13	5	50

The withdrawal of 7,700 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente-Las Vegas route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-67, about 50 percent of the route's length would be in areas with Designated Groundwater Basins, where the potential for groundwater depletion is watched carefully by the Nevada State Engineer's office. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 3,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for a short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer

stations and routes. This section discusses construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente-Las Vegas route.

Construction. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station siting locations and impacts to biological resources from construction of the station.

The predominant land cover types along the Caliente-Las Vegas route are creosote-bursage and Mojave mixed scrub (TRW 1999k, page 3-32). The regional area for each vegetation type is extensive (Utah State University 1996, GAP data). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

Three threatened or endangered species occur along the route (TRW 1999k, page 3-33). The desert tortoise occurs along the southern part of the route from near Alamo to Yucca Mountain (Bury and Germano 1984, pages 57 to 72). An approximately 100-kilometer (62-mile) section of U.S. 93 from Maynard Lake to the junction with I-15 is critical habitat for the desert tortoise (50 CFR 17.95). Slight alterations of habitat immediately adjacent to existing roads would have only small impacts on desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than 1 kilometer (0.6 mile) on either side of roads with average daily traffic greater than 180 vehicles (Bury and Germano 1984, pages 57 to 72). Two endangered species—the Pahranagat roundtail chub and the White River springfish—occur in Ash Springs or its outflow. The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). Because improvements would occur on the existing roadway and the Nevada Department of Transportation would use standard practices to reduce erosion and runoff, road improvements would not adversely affect the species living there. Nine other special status species occur within 100 meters (330 feet) of this route (TRW 1999k, page 3-33). Four of these species occur at Ash Springs or its outflow, and would not be affected for the reasons stated above for this site. The other five species would not be affected because construction activities would be restricted to the existing right-of-way, so occupied habitat would not be destroyed.

This route would cross eight areas designated as game habitat (TRW 1999k, page 3-33). Habitat in these areas would be reduced slightly due to construction activities along existing roads. Game animals could be disrupted if they were in these areas during construction.

Seven springs, riparian areas, or other wet areas occur near this route (TRW 1999k, page 3-33). These areas may be jurisdictional wetlands or other waters of the United States. However, no formal delineation has occurred. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE will work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife by the additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

Cultural Resources

Section 6.3.3.1 discusses impacts to cultural resources that would be common to all the heavy-haul truck implementing alternatives.

There are four archaeological sites near the Caliente intermodal station locations, none of which has been evaluated for eligibility for the *National Register of Historic Places* (TRW 1999m, pages 2-19 to 2-47). Because no systematic ethnographic field studies have been completed for the Caliente-Las Vegas routes and the intermodal transfer station in Caliente, specific impacts to culturally important sites, areas, or resources cannot be determined at this time. The Caliente-Las Vegas route follows a portion of U.S. 95 that passes through approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Indian Reservation, and the U.S. 93 segment passes near the Moapa Indian Reservation.

Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente-Las Vegas route. Impacts from the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.2.1.

Construction. Industrial safety impacts on workers from upgrading highways for the Caliente-Las Vegas route would be small (Table 6-68). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities from commuting workers and the movement of construction materials and equipment. Table 6-69 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-68. Impacts to workers from industrial hazards from upgrading highways along the Caliente-Las Vegas route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	18	270
Lost workday cases	8	140
Fatalities	0.1	0.5
Noninvolved workers[d]		
Total recordable cases	4	12
Lost workday cases	2	6
Fatalities	0.01	0.01
Totals[e]		
Total recordable cases	22	280
Lost workday cases	10	150
Fatalities	0.1	0.5

a. Impacts are totals over about 2 years.
b. Includes impacts from periodic maintenance and resurfacing activities. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts listed in Table 6-70 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Caliente-Las Vegas route. These impacts would include those from transportation along the route and along railways in Nevada leading to the Caliente intermodal transfer station. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

This section describes socioeconomic impacts that would occur from upgrading and using highways on the Caliente-Las Vegas route. It includes impacts from constructing and operating an intermodal transfer station in Caliente.

Construction. Socioeconomic impacts from upgrading highways for the Caliente-Las Vegas route and building an intermodal transfer station would be transient, occurring over short periods and be spread among the communities and counties along the route. Employment for route upgrades and intermodal transfer station construction would be about 290 workers. The highway upgrades would cost about $93

Table 6-69. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente-Las Vegas route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	61,000,000	1.1	0.0044
Commuting workers	37,000,000	0.4	0.0026
Subtotals	*98,000,000*	*1.5*	*0.007*
Operations[c]			
Commuting workers	200,000,000	2.0	0.014
Totals	***300,000,000***	***3.5***	***0.021***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 2 years.
c. Impacts are totals over about 24 years.

Table 6-70. Health impacts from incident-free Nevada transportation for the Caliente-Las Vegas route heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	220	520	740
Estimated latent cancer fatality	0.09	0.21	0.30
Public			
Collective dose (person-rem)	270	1,300	1,600
Estimated latent cancer fatality	0.13	0.64	0.77
Estimated vehicle emission-related fatalities	0.00014	0.0040	0.0041

a. Impacts are totals for 24 years (2010 to 2033).
b. Totals might differ from sums of values due to rounding.

million (1998 dollars) and would require 25 months to complete. Constructing an intermodal transfer station would cost $24 million and require 1.5 years.

At its peak, increased employment for both construction workers (direct workers) and other workers who would be employed either because of highway upgrade and intermodal transfer station construction projects or as a result of the economic activity generated by the projects (indirect workers) would be about 810. The change in employment for Clark, Nye, and other Nevada counties except Lincoln County would be less than 1 percent of the counties employment base. For Lincoln County, the increase in employment would be as much as 2 percent. This increase would be a moderate impact. However, it would be within historic short-term changes in employment for the county.

As a result of increased employment, population would be affected. The projected increases in population would reach a peak in 2009. During that year, the cumulative increase in population would be about 540. Population changes for Clark, Lincoln, and Nye Counties from increased employment would be less than 1 percent above the baseline. Thus, employment and population impacts from highway improvement and intermodal transfer station construction projects would be small in comparison to existing employment and populations in the affected counties.

The increased real disposable income in the affected counties would reach a peak in 2008 at $20.1 million. Gross Regional Product would peak in 2008 at $35.3 million. Increased State and local government expenditures from highway improvement and intermodal transfer station construction projects would reach their peak in 2009 at $1.5 million.

Changes to real disposable income, Gross Regional Product, and government expenditures would be small—less than 1 percent for Clark, Lincoln, Nye, and the other Nevada counties.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and last until 2033. An operations workforce of 26 would be required for the intermodal transfer station. For the national mostly rail transportation scenario, the station would operate throughout the year. The analysis assumed that operations workers would reside in Lincoln County. The workforce for heavy-haul truck operations, including escorts, would be 120 workers.

Employment would be likely to remain relatively level throughout operations. Operations employment (direct and indirect) would average about 250 workers. The analysis assumed that about 100 of these workers would be employed in Lincoln County. The impact on population would be about 460 additional residents, about 130 in Lincoln County. Employment and population increases for Lincoln County, which would experience the largest changes as a fraction of the baseline, would be about 3.5 percent. These employment and population impacts would be moderate in comparison to the existing employment and population levels for the county and would be within the range of historic changes in the county.

Real disposable income in the region of influence (Clark, Lincoln, and Nye Counties, and the remainder of Nevada) from operating an intermodal transfer station in Caliente and operating heavy-haul trucks based in Caliente would rise throughout operations, starting at $2.7 million in 2010 and increasing to $11.3 million in 2033. Gross Regional Product would also rise during operations, starting at $4.7 million in 2010 and increasing to $13.8 million in 2033. Annual State and local government expenditures would increase from $340,000 in 2010 to about $2.5 million in 2033. Increases to real disposable income, Gross Regional Product, and government expenditures would be moderate in Lincoln County for the Caliente-Las Vegas route. Changes in real disposable income and government expenditures for the county would be about 2.5 and 1.8 percent, respectively. The projected change in gross regional product for the county would be 4.3 percent. This change would be within historic short-term changes for Lincoln County.

Because of the periodic need to resurface highways used by the heavy-haul trucks, employment would increase in the years these projects occurred. During those years, employment (direct and indirect) in the region would increase by 190 for a Caliente-Las Vegas route. Overall, employment changes from periodic (every 8 years) highway-resurfacing projects would be less than 1 percent in Clark, Nye, and Lincoln counties for the route. The impacts of the increases would be small.

Population increases would follow the increases in employment for highway resurfacing projects. Overall, the short-term increase in population in Nevada would be about 100 for a Caliente-Las Vegas route. As a consequence, impacts to employment and population in affected counties in Nevada would be small and transient for highway resurfacing projects.

Noise

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Caliente-Las Vegas heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1.

Construction activities for upgrading highways along the Caliente-Las Vegas route would occur on all sections with the exception of the section of I-15 between its intersection with U.S. 93 and the planned Northern Las Vegas Beltway. Northern Las Vegas, the Towns of Caliente and Indian Springs, and the small rural communities of Crystal Springs and Alamo would fall within the 2000-meter (6,560-foot) region of influence for construction noise. The potential number of inhabitants would be highest for the route near the greater Las Vegas area. There are also small rural communities and towns along the route.

Because the shipments would pass through a large population area, there would be a potential for noise impacts along the route.

Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente-Las Vegas heavy-haul truck implementing alternative.

Construction. The construction of the Caliente intermodal transfer station would produce the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-71 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente-Las Vegas route. These quantities would be unlikely to be large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-71. Utilities, energy, and materials required for upgrades along the Caliente-Las Vegas route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Las Vegas	377	5.5	110	0.55	0.80	21

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

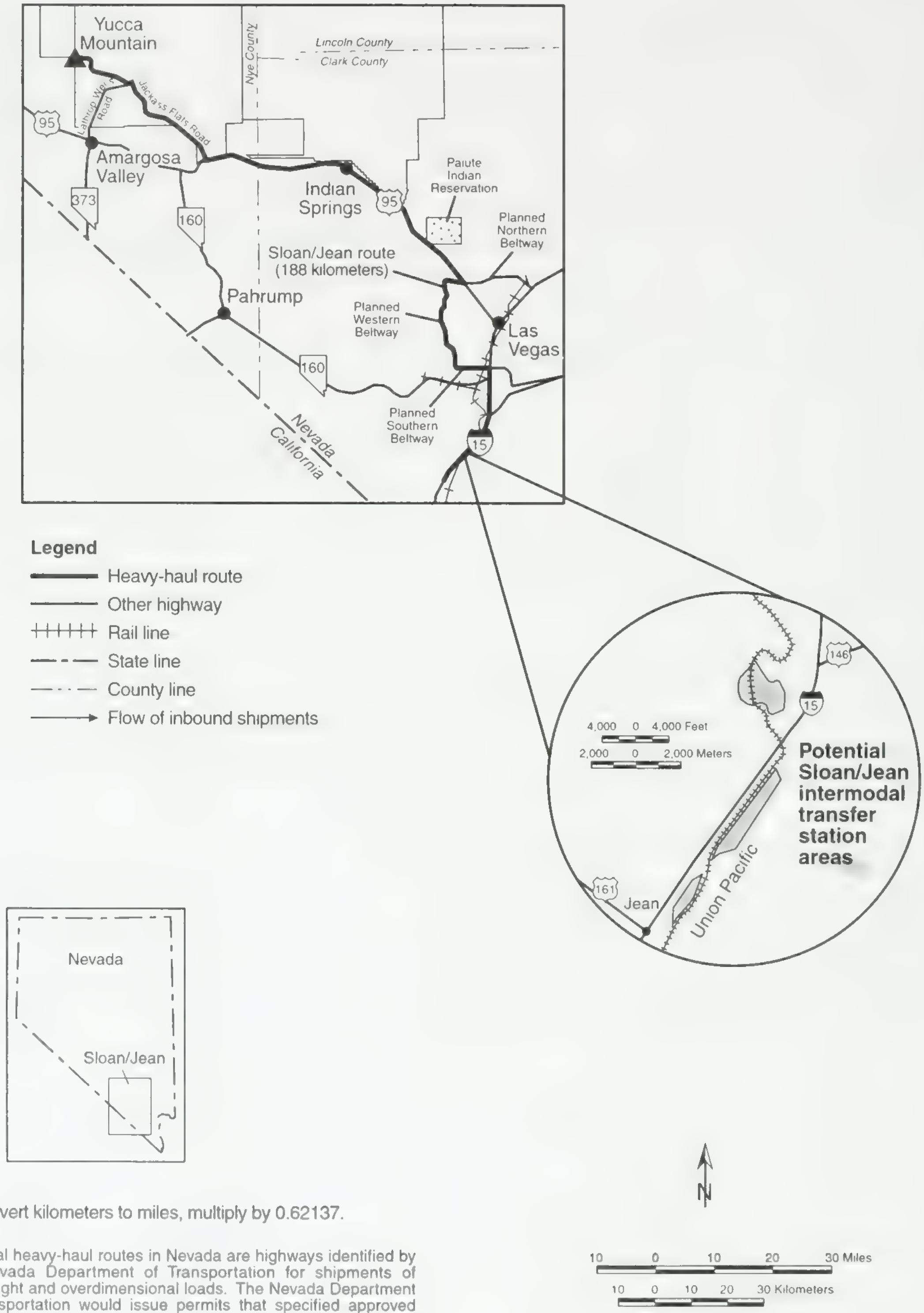
Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.4 *Sloan/Jean Route Implementing Alternative*

The Sloan/Jean route (Figure 6-21) is about 188 kilometers (117 miles) long. Heavy-haul trucks and escorts leaving a Sloan/Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

The three potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific sidings at Sloan and Jean. One area is on the east side of I-15, south of the Union Pacific rail underpass at I-15, and has an area of 3.3 square kilometers (811 acres). The second, which has an area of 3.1 square kilometers (758 acres), is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15, and has an area of 1.0 square kilometer (257 acres).

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise; and utilities, energy, and materials. Impacts that would occur to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are,



To convert kilometers to miles, multiply by 0.62137.

Potential heavy-haul routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

Source: Modified from DOE (1998g, all)

Figure 6-21. Sloan/Jean heavy-haul truck route.

therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Sloan/Jean intermodal transfer station, upgrades of highways, and heavy-haul truck operations over the Sloan/Jean route. Chapter 3, Section 3.2.2.2.1, describes the Sloan/Jean intermodal transfer station site and the associated truck route.

Construction. At the Sloan/Jean intermodal station area there could be potential impacts related to the current use of the land. All three Sloan/Jean candidate sites are on land administered by the Bureau of Land Management. The northernmost area is in the Spring Mountain grazing allotment and the Ivanpah Valley desert tortoise area of critical environmental concern. The Bureau of Land Management has designated land east of the railroad as a gravel pit (community pit), but that land has not been worked; the area is open to fluid mineral leasing but closed to mining claims. The two southern areas are in the Jean Lake grazing allotment, a special recreation management area, and an area designated as available for sale or transfer. Both southern areas are open to fluid mineral leasing and mining claims (TRW 1999f, page 21).

The Sloan/Jean route would require considerable improvements at the interchange with I-15. These disturbed areas probably would be subject to increased erosion for at least some of the construction phase. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. Drainage control along the route probably would remain as it is now. These combined measures would minimize the potential for adverse impacts to soils. Section 6.3.3.1 discusses other impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Sloan/Jean intermodal transfer station or the Sloan/Jean route other than those described in Section 6.3.3.1.

Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station and heavy-haul truck operation along the Sloan/Jean upgraded route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10} and $PM_{2.5}$).

Construction. Section 6.3.3.1 discusses air quality impacts for the construction of the Sloan/Jean intermodal transfer station. These impacts would be a result of emissions from construction equipment and fugitive dust from earth excavation and construction vehicle traffic. The Sloan/Jean intermodal transfer station locations are near or in the Las Vegas air basin, which is in nonattainment with national Ambient Air Quality Standards for carbon monoxide and PM_{10} (FHWA 1996, pages 3-53 and 3-54). Because the station could affect the air basin, DOE compared its estimated annual emission rates to the General Conformity Rule annual emission threshold levels for carbon monoxide and particulate matter. Based on the predicted annual rates, the construction of the Sloan/Jean intermodal transfer station would emit about 2 percent of the emission threshold level for carbon monoxide and 48 percent for PM_{10}. Based on this evaluation, a general conformity analysis would not be required for construction of the intermodal transfer station.

Section 6.3.3.1 also discusses the air quality impacts from upgrades of the Sloan/Jean route for heavy-haul truck transport. These impacts would be a result of emissions from construction equipment and fugitive dust from earth excavation and construction vehicle traffic. Construction equipment design and controls would ensure that emissions did not exceed ambient air quality standards. Most of the road

upgrades would occur in areas that are in attainment for criteria pollutants. However, portions of the upgrades would occur in the Las Vegas Valley airshed, which is in nonattainment for carbon monoxide and PM_{10}.

Operations. Section 6.3.3.1 discusses the air quality impacts associated with the operation of the Sloan/Jean intermodal transfer station and from emissions of heavy-haul trucks. The potential station locations are near or in the Las Vegas air basin, which is in nonattainment for carbon monoxide and PM_{10}. Because the operation of a station could affect the air basin, DOE compared the estimated annual emission rates to the General Conformity Rule annual emission threshold levels for carbon monoxide and particulate matter. Based on the predicted annual emission rates, the operation of the Sloan/Jean intermodal transfer station would emit about 9 percent and 2 percent of the emission threshold levels for carbon monoxide and PM_{10}, respectively. Therefore, a general conformity analysis would not be required for operation of the intermodal transfer station.

The Sloan/Jean route would involve heavy-haul trucks passing through the Las Vegas Valley airshed, which is in nonattainment for carbon monoxide and PM_{10}. The air quality impacts to this airshed from the operation of four or five trucks a day would be very small in comparison to the amount of pollutants emitted from automobile travel and other commercial vehicles in the basin.

Hydrology

DOE anticipates limited impacts to surface water and groundwater during upgrades to Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these impacts as well as those from the construction and operation of an intermodal transfer station and operation of trucks on the Sloan/Jean route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed in that section apply to surface water along the Sloan/Jean route.

Groundwater

Construction. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Upgrades to the Sloan/Jean route would not require any water wells. The road upgrades would require an estimated total of about 9,200 cubic meters (8 acre-feet) of water (LeFever 1998b, all). Options for obtaining this water would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 500 truckloads) to construction sites, or use a combination of these two actions.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul routes.

Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Sloan/Jean intermodal station and route.

Construction. Potential Sloan/Jean intermodal transfer station site locations are between the existing Union Pacific rail sidings at Sloan and Jean. The dominant land cover type in these areas is

creosote-bursage (TRW 1999k, page 3-36). The land cover type at the site is extensive in the region (Utah State University 1996, GAP data).

The three sites that DOE is considering for a Sloan/Jean intermodal transfer station are in the range of the desert tortoise, but none of the areas are critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of tortoise habitat. The likelihood of tortoise death or injury due to construction activities would be small if DOE moved tortoises in the immediate area to a safe habitat. The pinto beardtongue (classed as sensitive by the Bureau of Land Management) occurs in two of the proposed locations of the Sloan/Jean intermodal transfer station (TRW 1999k, page 3-36). If one of these sites was selected, DOE would conduct pre-activity surveys for this plant species and would avoid disturbance of occupied areas if possible. There are no designated game habitats at the proposed location for the intermodal transfer station, and there are no springs or other areas that could be classified as wetlands (TRW 1999k, page 3-36).

Predominant land cover types in nonurban areas along the route are creosote-bursage and Mojave mixed scrub (TRW 1999k, page 3-36). The regional area for each vegetation type is extensive. Because areas disturbed by upgrade activities would be in or adjacent to existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only threatened or endangered species that occurs along the route is the desert tortoise. Desert tortoise habitat occurs throughout the length of the route (Bury and Germano 1984, pages 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon along heavily traveled roads (Bury and Germano 1984, Appendix D, page D12). Four other special status species occur along this route (TRW 1999k, page 3-36), but construction activities would be limited to the road and adjacent areas; occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat and there are no springs or wetlands near the route. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual or regional permits, as appropriate (TRW 1999k, page 3-36). Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

Cultural Resources

Section 6.3.3.1 discusses the impacts to cultural resources that would be common to all the heavy-haul truck implementing alternatives.

There are seven archaeological sites near the Sloan/Jean intermodal transfer station locations, none of which has been evaluated for potential eligibility for the *National Register of Historical Places*.

The Sloan/Jean route follows a portion of U.S. 95 that passes through approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Indian Reservation. However, no field studies have been completed for the route. Therefore, specific impacts to culturally important sites, areas, or resources cannot be determined at this time.

Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Sloan/Jean route. Impacts from the associated intermodal transfer station in the Sloan/Jean area would be the same as those discussed in Section 6.3.3.1.

Construction. Industrial safety impacts on workers from upgrading highways for the Sloan/Jean route would be small (Table 6-72). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-73 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-72. Health impacts to workers from industrial hazards from upgrading highways along the Sloan/Jean route.

Group and industrial impact category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	10	160
Lost workday cases	4	90
Fatalities	0.07	0.3
Noninvolved workers[d]		
Total recordable cases	2	7
Lost workday cases	1	4
Fatalities	0	0.007
Totals[e]		
Total recordable cases	12	170
Lost workday cases	5	94
Fatalities	0.07	0.3

a. Impacts are totals over about 6 months.
b. Includes impacts for periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-74 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Sloan/Jean route. These impacts would include transportation along the Sloan/Jean route as well as transportation along railways in Nevada leading to the Sloan/Jean intermodal transfer station. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

This section describes socioeconomic impacts that would occur from upgrading and using highways along the Sloan/Jean route and building an intermodal transfer station for heavy-haul truck transportation. It includes the impacts of operating an intermodal transfer station near Sloan/Jean in southern Nevada.

Table 6-73. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Sloan/Jean route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	32,000,000	0.6	0.0023
Commuting workers	21,000,000	0.2	0.0015
Subtotals	*53,000,000*	*0.8*	*0.0038*
Operations[c]			
Commuting workers	120,000,000	1.2	0.0089
Totals	***170,000,000***	***2.0***	***0.013***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 6 months.
c. Impacts are totals over 24 years.

Construction. Socioeconomic impacts from upgrading highways for a Sloan/Jean route and building an intermodal transfer station would be transient, occur over short periods, and be spread among the communities and counties along the route. Employment for route upgrades and intermodal transfer station construction would be about 230 workers. Upgrading highways for the route would cost about

Table 6-74. Health impacts from incident-free Nevada transportation for the Sloan/Jean heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	220	490	710
Estimated latent cancer fatalities	0.09	0.2	0.29
Public			
Collective dose (person-rem)	270	750	1,000
Estimated latent cancer fatalities	0.13	0.38	0.51
Estimated vehicle emission-related fatalities	0.00014	0.015	0.015

a. Impacts are totals for 24 years (2010 to 2033).
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

$20 million (1998 dollars) and would require 6 months to complete. Constructing an intermodal transfer station would cost $24 million (1998 dollars) and require 1.5 years.

Employment for both construction workers (direct workers) and other workers who would be employed either because of highway upgrade and intermodal transfer station projects or as a result of the economic activity generated by the project (indirect workers) would be about 720. The change in employment for Clark, Nye, and Lincoln Counties, and the remainder of Nevada would be much less than 1 percent of their employment bases.

Increased employment would affect population. The projected increases in population would reach a peak of about 560 in 2009. Population changes for Clark, Nye, and Lincoln Counties, and the remainder of Nevada that would arise from increased employment would be much less than 1 percent above the baseline. Thus, employment and population impacts would be small in comparison to existing employment and populations in the affected counties.

Increased real disposable income in Clark, Nye, and Lincoln Counties, and the remainder of Nevada for highway improvements and intermodal transfer station construction would peak in 2009 at $19.9 million. Gross Regional Product would peak in 2009 at $33.6 million. Increased State and local government expenditures resulting from highway upgrade and intermodal transfer station construction projects would reach their peak in 2009 at $1.5 million. Changes to real disposable income, Gross Regional Product, and government expenditures would be small—much less than 1 percent for Clark, Nye, and Lincoln Counties, and the remainder of Nevada. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and last until 2033. An operations workforce of about 26 would be required for the intermodal transfer station. For the national mostly rail transportation scenario, the station would operate throughout the year. The workforce for heavy-haul truck operations over a Sloan/Jean route, including shipment escorts, would be about 66 workers. The analysis assumed that operations workers would reside in Clark County.

Employment would be likely to remain relatively level throughout operations. Operations employment (direct and indirect) would be about 120 workers. The impact on population would be about 200 additional residents. Employment and population increases for Clark, Nye, and Lincoln Counties, and the remainder of Nevada would be small in comparison to existing employment and population levels.

Real disposable income from operating an intermodal transfer station in Sloan/Jean and operating heavy-haul trucks based at Sloan/Jean would rise throughout operations, starting at $1.6 million in 2010 and increasing to $5.4 million in 2033. Gross Regional Product would also rise during operations, starting at $2.3 million in 2010 and increasing to $4.7 million in 2033. Annual State and local government expenditures would increase from $240,000 in 2010 to $840,000 in 2033. Increases to real disposable income, Gross Regional Product, and government expenditures would be small—much less than 1 percent in Clark, Nye, and Lincoln Counties, and the remainder of Nevada for the Sloan/Jean route.

Because of the periodic need to resurface highways used by the heavy-haul trucks, employment would increase in the years these projects occurred. During those years, employment (direct and indirect) in the region would increase by about 100 for a Sloan/Jean route. Overall, employment changes from periodic (every 8 years) highway resurfacing projects would be small in Clark, Nye, and Lincoln Counties, and the remainder of Nevada for the route. As a consequence, impacts to employment and population in affected counties in Nevada would be small and transient for highway resurfacing projects.

Noise

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Construction. There are residences and commercial businesses near the three potential sites for an intermodal transfer station in the Sloan/Jean area. Construction noise would occur during daylight hours and would be a temporary source of elevated noise in the area. Nighttime noise impacts would be unlikely because construction activities would not occur at night.

For the Sloan/Jean route, southern and western Las Vegas, the Town of Indian Springs, and the small rural community of Jean would be within the 2,000-meter (6,560-foot) region of influence for construction noise. Construction activities would occur on all sections of the route with the exception of I-15 between its interchange at Sloan and the planned Southern Las Vegas Beltway. Because the number of inhabitants of the region of influence would be high because the route passes around the greater Las Vegas area and includes other small rural communities and towns, there is a potential for construction noise impacts.

Operations. The presence of residences and commercial businesses near the Sloan/Jean location would make an intermodal transfer station a potential source of more noise complaints than the more remote locations. However, because operational noise in the vicinity of Sloan/Jean would not be much higher than the levels associated with most other light industrial areas, noise impacts would be unlikely. Railcar switching would be the greatest source of noise.

However, there would be a potential for noise impacts from heavy-haul truck operations along the Sloan/Jean route, based on community size and the number of affected communities. The route passes the City of Las Vegas, one established town, and one rural area on its way to the Yucca Mountain site.

Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Construction. The construction of the Sloan/Jean intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-75 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Sloan/Jean route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-75. Utilities, energy, and materials required for upgrades along the Sloan/Jean route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Sloan/Jean	188	1.7	29	0.24	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses utilities, energy, and materials needs for operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.5 *Apex/Dry Lake Route Implementing Alternative*

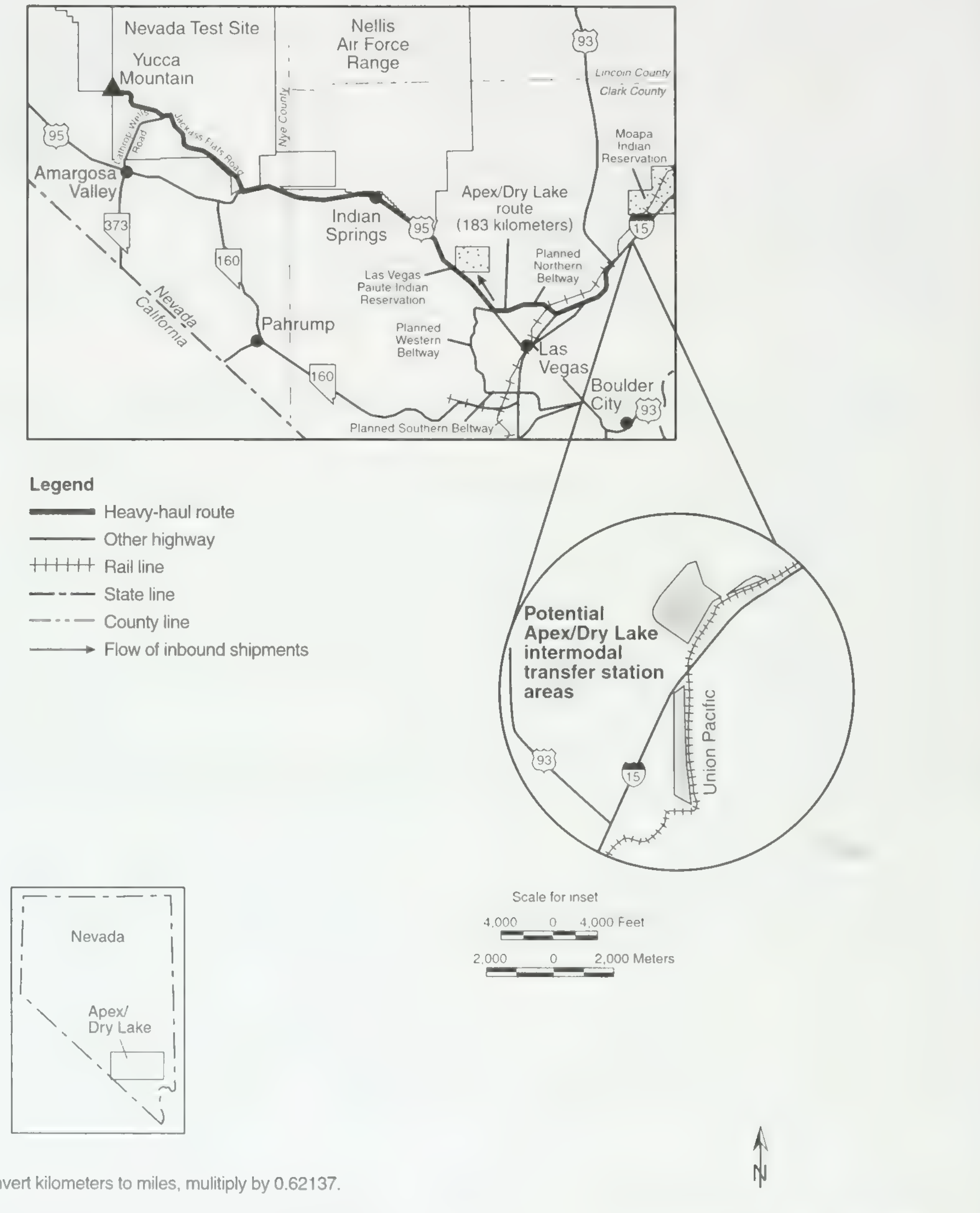
The Apex/Dry Lake route (Figure 6-22) is about 183 kilometers (114 miles) long. Heavy-haul trucks and escorts would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway and travel west on the beltway. They would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

The potential sites for the Apex/Dry Lake intermodal transfer station are in areas northeast of Las Vegas between the Union Pacific rail sidings at Dry Lake and at Apex. Two large contiguous areas are available for station siting. The first area is directly adjacent to the Dry Lake siding. The Dry Lake area is large [3.5 square kilometers (877 acres)] and has flat topography along the west side of the Union Pacific line. It is bounded by hills to the north and by a wash and private land to the south. The second area, which is on the east side of I-15 adjacent to the Union Pacific line and south of where the main Union Pacific line crosses I-15, has an area of 0.96 square kilometers (237 acres). Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary.

The following sections address impacts that would occur to land use; biological resources and soils; occupational and public health and safety; socioeconomics; and utilities, energy, and materials. Impacts to air quality, noise, and hydrology from the construction and operation of an intermodal transfer station, upgrading of highways, and operation of heavy-haul trucks on an Apex/Dry Lake route would be the same as those discussed in Section 6.3.3.2.4 for a Sloan/Jean route. Impacts to cultural resources, aesthetics, and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

Land Use and Ownership

This section describes estimated land-use impacts that could occur from the construction and operation of the Apex/Dry Lake intermodal transfer station, upgrades of highways, and heavy-haul truck operations on the Apex/Dry Lake route. Chapter 3, Section 3.2.2.2.1, describes the Apex/Dry Lake intermodal transfer station site and associated truck route.



To convert kilometers to miles, mulitiply by 0.62137.

Potential heavy-haul routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

Source: Modified from DOE (1998g, all)

Figure 6-22. Apex/Dry Lake heavy-haul truck route.

Construction. The Apex/Dry Lake intermodal transfer station site could have potential impacts related to the current use of the land. Both potential Apex/Dry Lake site areas are on land administered by the Bureau of Land Management. The northern area has several infrastructure corridors (power line, telephone, and road rights-of-way). It is in the Dry Lake grazing allotment and a planned utility corridor. It is also open to mineral leasing and mining claims. One area has been designated as available for sale or transfer.

The Apex/Dry Lake route would require considerable improvements at the interchange at I-15. These disturbed areas probably would be subject to increased erosion for at least some of the construction phase. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. Drainage control along the route probably would remain as it is now. These combined measures would minimize the potential for adverse impacts to soils. Section 6.3.3.1 discusses impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Apex/Dry Lake intermodal transfer station or the Apex/Dry Lake route other than those described in Section 6.3.3.1.

Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Apex/Dry Lake intermodal station and route.

Construction. DOE has identified three areas for the construction of an Apex/Dry Lake intermodal transfer station. The predominant land cover type at these sites (creosote-bursage) is extensively distributed in the region (TRW 1999k, page 3-36; Utah State University 1996, GAP data). Considerable industrial development has occurred near the potential sites. The three sites are in the range of the threatened desert tortoise, although none is in an area considered to be critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of desert tortoise habitat. The likelihood of death or injury to tortoises due to construction activities would be small if DOE conducted surveys for tortoises in areas to be disturbed and moved tortoises in the immediate area out of harm's way. Geyer's milk vetch (BLM sensitive) occurs on the southern edge of one of the proposed locations of the Apex/Dry Lake intermodal transfer station (TRW 1999k, page 3-37). If this location for an intermodal transfer station was selected, DOE would conduct pre-activity surveys for this plant's species and would avoid occupied habitat if possible. There are no designated game habitats at the proposed locations for the intermodal transfer station, or any springs or other areas that could be classified as wetlands (TRW 1999k, page 3-37).

The predominant land cover types along the Apex/Dry Lake heavy-haul route are creosote-bursage and Mojave mixed scrub, which are common throughout this region (TRW 1999k, page 3-34; Utah State University 1996, GAP data). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only resident threatened or endangered species that occurs along the Apex/Dry Lake route is the desert tortoise. Desert tortoise habitat occurs along the entire length of the route (Bury and Germano 1984, pages 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon adjacent to heavily traveled roads (Bury and Germano 1984, Appendix D, page D12). Three other special status species occur along this route (TRW 1999k, page 3-35) but because

construction activities would be limited to the road and adjacent areas, occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat or springs or possible wetlands (TRW 1999k, page 3-35). The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual, regional, or nationwide permits, as appropriate. Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impact to soils would be small.

Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Apex/Dry Lake route. The impacts of the Apex/Dry Lake intermodal transfer station would be the same as those discussed in Section 6.3.3.1.

Construction. Industrial safety impacts on workers from upgrading highways for the Apex/Dry Lake route would be small (see Table 6-76). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatalities for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-77 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-76. Impacts to workers from industrial hazards from upgrading highways along the Apex/Dry Lake route.

Group and trauma category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	9	160
Lost workday cases	4	90
Fatalities	0.06	0.3
Noninvolved workers[d]		
Total recordable cases	2	7
Lost workday cases	1	4
Fatalities	0.004	0.007
Totals[e]		
Total recordable cases	11	170
Lost workday cases	5	94
Fatalities	0.06	0.3

a. Impacts are totals over about 6 months.
b. Includes periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts listed in Table 6-78 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the route. These impacts would include transportation along the route as well as transportation along railways in Nevada leading to an Apex/Dry Lake intermodal transfer station. The table includes the impacts of 2,600 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks.

Socioeconomics

This section describes socioeconomic impacts that would occur from upgrading and using highways along the Apex/Dry Lake route and building an intermodal transfer station for heavy-haul truck transportation. It includes impacts from the operation of an intermodal transfer station at the Apex/Dry Lake site in Clark County.

Construction. Socioeconomic impacts from upgrading highways for an Apex/Dry Lake route and building an intermodal transfer station would be transient, occur over short periods, and be spread among

Table 6-77. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Apex/Dry Lake route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	32,000,000	0.6	0.0023
Commuting workers	20,000,000	0.2	0.0014
Subtotals	*52,000,000*	*0.8*	*0.0037*
Operations[c]			
Commuting workers	120,000,000	1.2	0.0089
Totals	***170,000,000***	***2.0***	***0.013***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 6 months.
c. Impacts are totals over 24 years.

Table 6-78. Health impacts[a] from incident-free Nevada transportation for the Apex/Dry Lake heavy-haul truck implementing alternative.

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	220	470	690
Estimated latent cancer fatalities	0.09	0.19	0.28
Public			
Collective dose (person-rem)	270	670	940
Estimated latent cancer fatalities	0.13	0.34	0.47
Estimated vehicle emission-related fatalities	0.00014	0.0029	0.0030

a. Impacts are totals for 24 years (2010 to 2033).
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

the communities and counties along the route. Employment for route upgrades and intermodal transfer station construction would be about 230 workers.

Upgrading highways for the Apex/Dry Lake route would cost $20 million (1998 dollars) and would require 6 months to complete. Constructing an intermodal transfer station would cost $24 million (1998 dollars) and require 1.5 years.

At its peak, increased employment for both construction workers (direct workers) and other workers who would be employed either because of highway upgrade and intermodal transfer station projects or as a result of the economic activity generated by the projects (indirect workers) would reach about 540. The change in employment for Clark, Lincoln, and Nye Counties, and the remainder of Nevada would be much less than 1 percent of the counties' employment bases.

Increased employment would also affect population. The projected increases in population would reach a peak of about 360 in 2009. Population changes for Clark, Lincoln, and Nye Counties, and the remainder of Nevada from increased employment would be much less than 1 percent above the baseline. Thus, employment and population impacts from highway upgrade and intermodal transfer station construction projects would be small in comparison to the existing employment and populations in the affected counties.

The increased real disposable income of people in the affected counties would reach a peak in 2009 at less than $14.6 million. Gross Regional Product would peak in 2009 at less than $26 million. Increased State and local government expenditures resulting from highway upgrade projects would reach their peak in

2009 at less than $1 million. (All dollar values reported in this section are in 1992 constant dollars unless otherwise stated.)

Changes to real disposable income, Gross Regional Product, and government expenditures would be small much less than 1 percent for Clark, Lincoln, and Nye Counties, and the remainder of Nevada.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and last until 2033. An operations workforce of about 26 would be required for the intermodal transfer station. For the national mostly rail transportation scenario, the station would operate throughout the year. The workforce for heavy-haul truck operations over an Apex/Dry Lake route, including shipment escorts, would be about 66 workers. The analysis assumed that operations workers would reside in Clark County.

Employment would be likely to remain relatively level throughout operations. Operations employment (direct and indirect) would be about 120 workers. The impact on population would be about 190 additional residents. Employment and population increases for Clark, Lincoln, and Nye Counties, and the remainder of Nevada would be small in comparison to existing employment and population levels.

Real disposable income from operating an intermodal transfer station at Apex/Dry Lake and operating heavy-haul trucks would rise throughout operations, starting at $1.6 million in 2010 and increasing to $5.4 million in 2033. Gross Regional Product would also rise during operations, starting at $2.3 million in 2010 and increasing to $4.7 million in 2033. Annual State and local government expenditures would increase from about $240,000 in 2010 to $840,000 in 2033. Increases to real disposable income, Gross Regional Product, and government expenditures would be small—much less than 1 percent in Clark, Lincoln, and Nye Counties, and the remainder of Nevada for the Apex/Dry Lake route.

Because of the periodic need to resurface highways used by the heavy-haul trucks, employment would increase in the years these projects occurred. During those years, employment (direct and indirect) in the region would increase by about 100 for an Apex/Dry Lake route. Overall, employment changes from periodic (every 8 years) highway resurfacing projects would be small in Clark, Lincoln, and Nye Counties, and the remainder of Nevada for the route.

Population increases would follow the increases in employment for highway resurfacing projects. Overall, the short-term increase in population would be about 100. As a consequence, impacts to employment and population in affected counties in Nevada would be small and transient for highway resurfacing projects.

Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Construction. The construction of the Apex/Dry Lake intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-79 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Apex/Dry Lake route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

Table 6-79. Utilities, energy, and materials required for upgrades along the Apex/Dry Lake route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Apex/Dry Lake	183	1.6	28	0.23	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.4 Environmental Justice Impacts in Nevada

The analysis considered existing highways and railroads that DOE would use in Nevada—I-15, the proposed Las Vegas Beltway; U.S. 95; five possible highway routes for heavy-haul trucks; the Union Pacific Railroad's mainlines in northern and southern Nevada; and alignments for a possible branch rail line in five rail corridors in the State. If DOE constructed and operated the repository, it would use combinations of these routes for shipments of spent nuclear fuel and high-level radioactive waste. DOE would use alternative preferred routes designated by the State of Nevada for highway shipments to the repository.

In general, the consequences of using a transportation route would occur close to the route. Thus, for transportation on a highway or railroad to affect a census block group for which environmental justice concerns could exist, the route would have to cross or be adjacent to the block group. Figure 3-23 shows the census block groups with minority percentages in Nevada. Figure 3-24 shows the census block groups with low-income percentages in Nevada. Figures 6-23 and 6-24 show the minority and low-income block groups, respectively, in the Las Vegas metropolitan area.

Portions of some routes would cross or be adjacent to Native American tribal lands. Highway routes avoid census block groups with high fractions of minority, low-income, or Native American populations with the exception of sections of I-15 that pass through the center of the Moapa Indian Reservation northeast of Las Vegas, Nevada; a 1.6-kilometer (1-mile) section of U.S. 95 across the southwest corner of the Las Vegas Paiute Indian Reservation; and sparsely populated areas of census block groups in the northern parts of Clark County. The Union Pacific Railroad's mainline tracks pass through the center of the Moapa Indian Reservation and through the center of Las Vegas, Nevada, crossing census block groups with high fractions of minority and low-income populations. Also, a branch rail line in the Valley Modified rail corridor would pass near the Las Vegas Paiute Indian Reservation, and the Caliente-Las Vegas and Apex/Dry Lake routes for heavy-haul trucks would pass near the Moapa Indian Reservation. None of the potential intermodal transfer station sites that DOE could use would be near a census block group with high minority or low-income populations, but an intermodal transfer station in the Apex/Dry Lake area could be as close as about 3 kilometers (2 miles) to the Moapa Indian Reservation.

Impacts along Nevada highways and railroads from the transportation of spent nuclear fuel and high-level radioactive waste would be small. The number of shipments in the mostly legal-weight truck and mostly rail scenarios would be small in comparison to the number of all other commercial shipments in southern Nevada. For comparison, under the mostly legal-weight truck scenario as many as five trucks carrying spent nuclear fuel would pass through the Moapa Indian Reservation on I-15 each day compared to daily traffic of more than 3,000 commercial trucks that use this section of highway (NDOT 1997, page 6; Cerocke 1998, all). Under the mostly rail scenario as many as 11 railcars per week carrying spent nuclear fuel could travel into southern Nevada compared to about 1,000 railcars each day for other

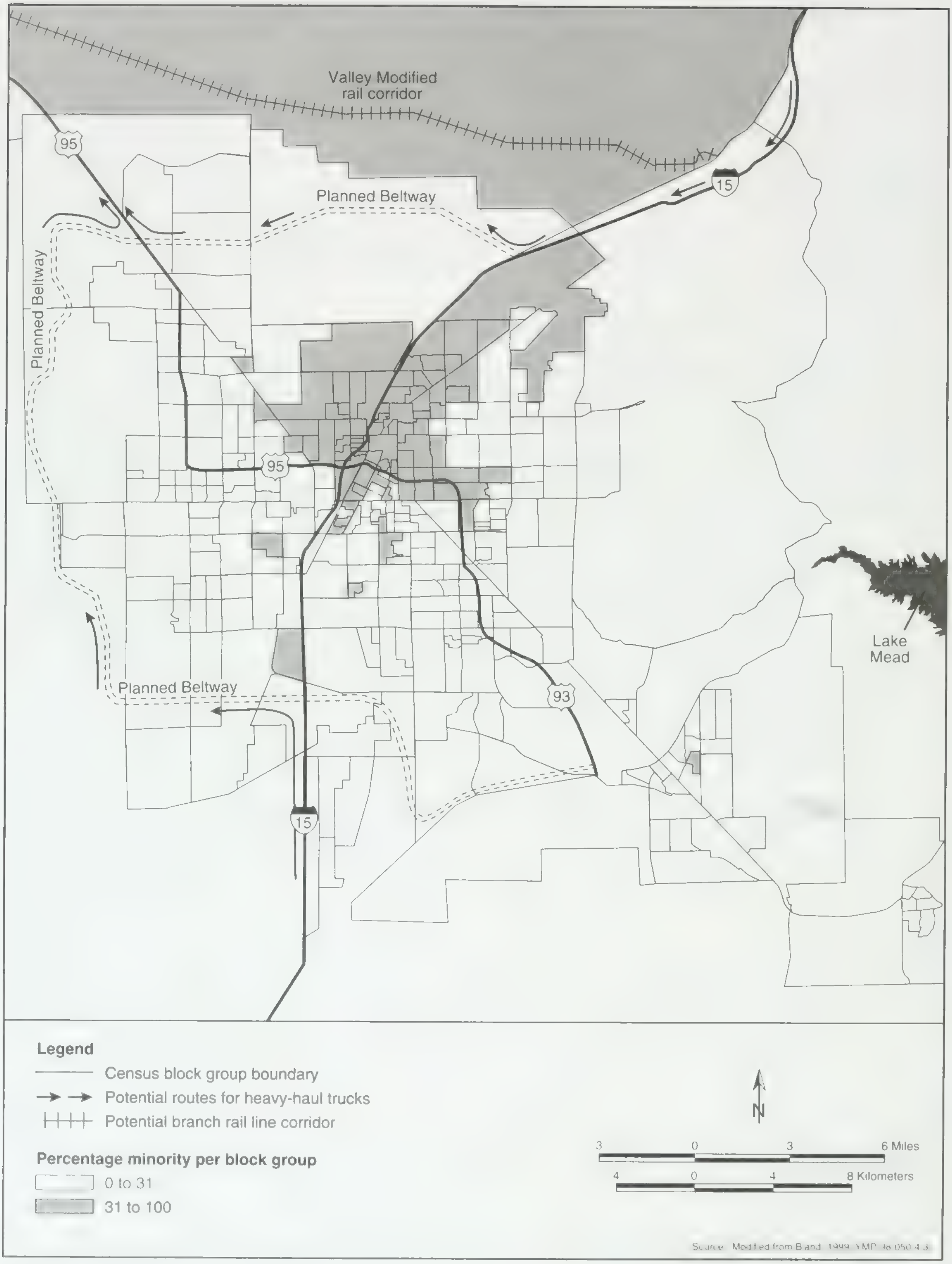


Figure 6-23. Minority census block groups in the Las Vegas metropolitan area.

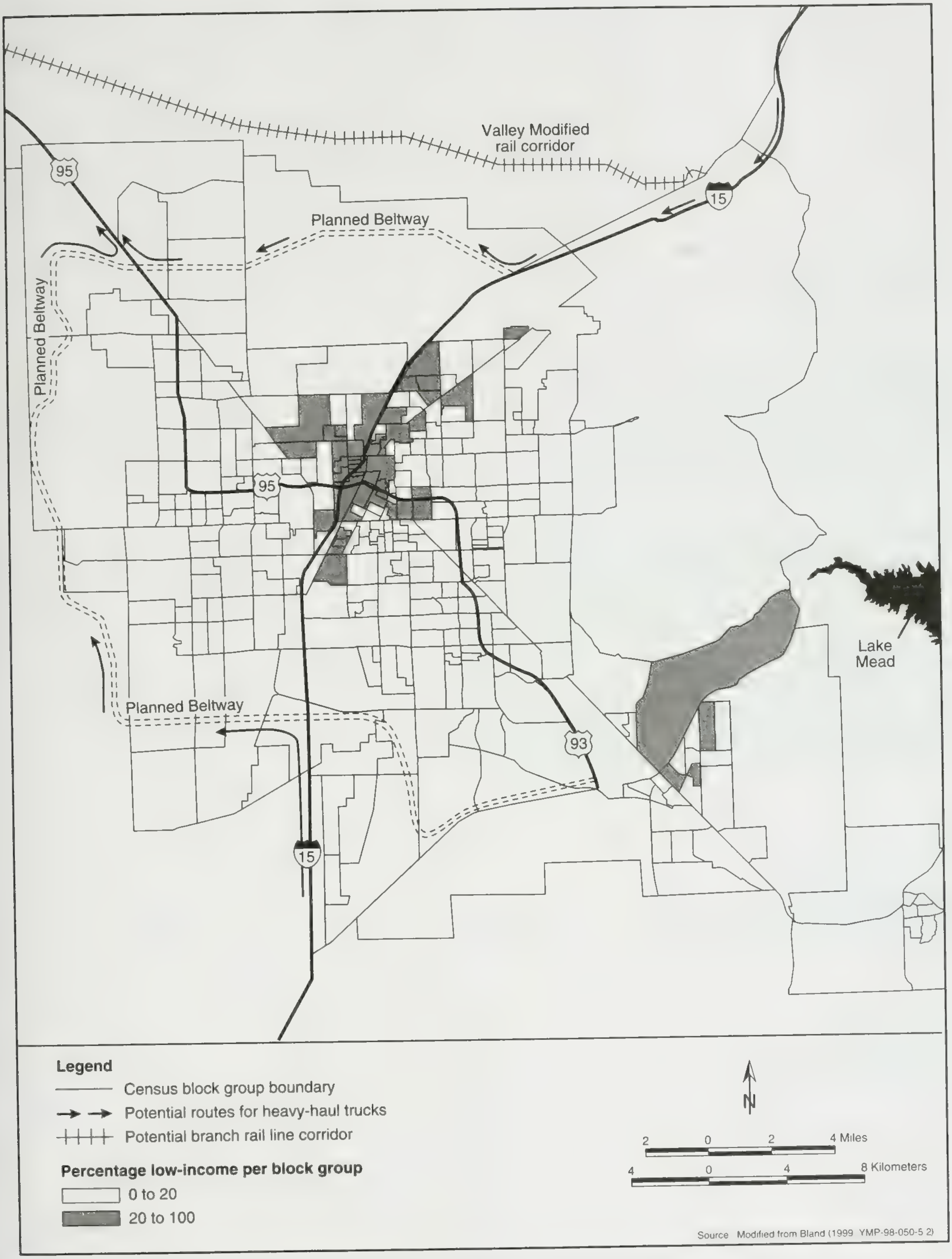


Figure 6-24. Low-income census block groups in the Las Vegas metropolitan area.

commodities. Thus, impacts from truck and rail traffic and emissions would be small for these shipments. The potential for accidents that could result in injuries or fatalities involving the shipments would also be small in comparison to the overall risk of accidents that would occur from other commercial traffic.

Up to about 10 percent of travel in southern Nevada by legal-weight trucks or railcars carrying spent nuclear fuel would be through Native American reservations and census block groups with high fractions of minorities or low-income populations. Because public health and safety impacts to all populations in Nevada would be small (less than 1 latent cancer fatality for incident-free transportation and 0.0005 latent cancer fatality for accidents over 24 years), the impacts to populations along 10 percent of the routes of travel would also be small. Because the probability would be small at any single location, the risk of an accident at a specific location would also be small. Thus, impacts to minority or low-income populations or to Native Americans in small communities along the routes would also be small and, therefore, unlikely to be disproportionately high and adverse.

In addition, for existing highways and mainline railroads, the added traffic would be minimal and shipments of spent nuclear fuel and high-level radioactive waste would be unlikely to affect land use, air quality, hydrology, biological resources and soils, cultural resources, socioeconomics, noise, or aesthetics. The analyses discussed in the preceding sections also determined that impacts to these resource areas from construction and operation of a branch rail line in any of the five potential rail corridors or construction of an intermodal transfer station and upgrading of highways in Nevada would be low.

Because the analyses did not identify large impacts for railroad and highway transportation of spent nuclear fuel and high-level radioactive waste in Nevada that would constitute credible adverse impacts on populations, workers, or individuals, adverse effects would be unlikely for any specific segment of the population, including minorities, low-income groups, and Native American tribes. Thus, there would be no environmental justice impacts in Nevada unique to shipment by legal-weight truck, by rail using one of the branch rail line implementing alternatives, or by heavy-haul truck using an intermodal transfer station and one of the five highway routes evaluated. In addition, environmental justice impacts would be unlikely for the construction of an intermodal transfer station and upgrading of highways for one of the possible heavy-haul truck routes. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

7

Environmental Impacts of the No-Action Alternative

7. ENVIRONMENTAL IMPACTS OF THE NO-ACTION ALTERNATIVE

This chapter describes the potential impacts associated with the No-Action Alternative described in Chapter 2. Under the No-Action Alternative and consistent with the Nuclear Waste Policy Act, as amended [NWPA, Section 113(c)(3)], the U.S. Department of Energy (DOE) would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States. The No-Action Alternative provides a baseline for comparison with the Proposed Action.

Under the No-Action Alternative, if DOE decided not to proceed with the development of a repository at Yucca Mountain, it would prepare a report to Congress, as required by the Nuclear Waste Policy Act, with its recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Under any future course that would include continued storage, both commercial and DOE sites would have an obligation to continue managing the spent nuclear fuel and high-level radioactive waste in a manner that protects public health and safety and the environment. Further, DOE intends to comply with the terms of existing consent orders and compliance agreements regarding the management of spent nuclear fuel and high-level radioactive waste. However, the future course that Congress, DOE, and the commercial utilities would take if Yucca Mountain did not receive a recommendation as a repository site remains highly uncertain. A number of possibilities could be pursued, including continued storage of the material at its present locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository (Chapter 1 identifies the process and alternative sites previously selected by DOE for technical study as potential geologic repository locations); development of new technologies (for example, transmutation); or reconsideration of other disposal alternatives to geologic disposal (as discussed in Section 2.3.1). Environmental considerations related to continued storage at current locations or at one or more centralized location(s) have been analyzed in other contexts for both commercial and DOE spent nuclear fuel and high-level radioactive waste in several documents. Table 7-1 lists representative studies related specifically to centralized or regionalized interim storage, including alternatives evaluated in DOE National Environmental Policy Act documents, and summarizes the relevant environmental considerations. Those studies contain more information on the potential environmental impacts of centralized or regional interim storage.

In light of the uncertainties described above, DOE decided to illustrate one set of possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios: long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years (Scenario 1), and long-term storage with no institutional controls after approximately 100 years (Scenario 2). DOE recognizes that neither of these scenarios would be likely to occur if there was a decision not to develop a repository at Yucca Mountain. However, the Department selected these two scenarios for analysis because they provide a baseline for comparison to the impacts from the Proposed Action and because they reflect a range of the impacts that could occur. Scenario 1, which includes an analysis of impacts under effective institutional controls for at least 10,000 years, is consistent with the portion of the analysis of the Proposed Action that includes an analysis of effective institutional controls for the first 100 years after closure. Scenario 2, in which the analysis does not consider institutional controls after approximately 100 years, is parallel to the portion of the Proposed Action analysis in which long-term performance after 100 years also does not include institutional controls. Chapter 2 describes the scenarios more fully. Appendix K contains detailed descriptions of the assumptions for each scenario.

Table 7-1. Documents that address storage of spent nuclear fuel and high-level radioactive waste[a] (page 1 of 4).

Title and scope of storage analysis	Environmental and other considerations
Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste (DOE 1980, all)	
Evaluates a proposal to provide interim storage of spent nuclear fuel from U.S. power reactors before final disposal. The proposal would include acceptance of a limited amount of foreign spent fuel if such actions would contribute to U.S. nonproliferation goals. Evaluates several generic interim storage facility alternatives, including centralized storage at a few large ISFS facilities.	Analyses include a description of a *generic interim storage site environment* based primarily on data for the midwestern United States, and potential environmental effects of such a facility for ISFS facilities. Impacts evaluated include: natural resources, radiological impacts, land use, water use, ecological resources, air quality, traffic, noise, socioeconomics, waste management, utilities, aesthetics, transportation (including both to ISFS facilities and from ISFS facilities to the disposition facility), and safeguards and security.
Recommendations on the Proposed Monitored Retrievable Storage Facility (Clinch River 1985, all)	
Evaluates DOE proposal to consider the Clinch River Breeder Reactor and ORR sites in Tennessee for an MRS facility. Performed by the Clinch River MRS Task Force, which included three study groups: environmental, socioeconomic, and transportation. Public meetings and site visits were conducted by the study groups. Separate reports by each study group are summarized in findings, concerns, anticipated impacts, and recommended mitigations.	The Environmental Study Group's final report presented concerns and recommended mitigations for MRS construction impacts, damage to ecosystem from construction, special nuclear risks of construction, highway construction impacts, radiation protection of workers and the public, airborne effluents, aqueous releases, hazards from cask rupture, earthquakes, flooding, long-term radionuclide containment, secondary waste stream, local control, offsite emergency response, past contamination of the ORR, environmental data from the ORR, and MRS becoming a permanent waste storage site. The Socioeconomic Study Group's final report identified concerns or potentially negative impacts of an MRS and possible mitigations for business recruitment and expansion, residential recruitment and retention, institutional trust, pre- and postoperational impacts and costs, tourism and aesthetics, site neighbors, and legislative issues. The Transportation Study Group's final report defined areas of potential major impacts (for example, independent inspections, upgrades of railroad tracks, routing and upgrades to preferred highway truck routes, escorts, emergency response plans and training, and requirements applicable to private carriers), and presented findings and recommendations on accident probabilities, barge transport, cask safety and contents, prenotification, and safeguards.

Table 7-1. Documents that address storage of spent nuclear fuel and high-level radioactive waste[a] (page 2 of 4).

Title and scope of storage analysis	Environmental and other considerations
Monitored Retrievable Storage Submission to Congress, Volume 2: Environmental Assessment for a Monitored Retrievable Storage Facility (DOE 1986b, Volume 2, all)	
Evaluates a proposal for the construction of a facility for monitored retrievable storage. Evaluates two facility design concepts at each of three candidate sites in Tennessee (Clinch River Breeder Reactor, ORR, and TVA Hartsville Nuclear Power Plant).	Evaluates impacts common to all three sites and unique to each site, including radiological, air quality, water quality and use, ecological resources, land use, socioeconomics, resource requirements, aesthetics, and transportation. Also evaluates relative advantages and disadvantages of the six site design combinations.
MRS System Study Summary Report (DOE 1989b, all)	
Evaluates the role of the MRS facility in the waste management system.	Provides additional support to the general conclusion that an MRS facility provides tangible benefits to a waste management system, as articulated in the DOE 1986 MRS proposal to Congress (DOE 1986b, Volume 2, all). Examines various system configurations in a series of separate publications: • Scenario development and system logistics • Facility design/schedule/cost implications • Alternative MRS storage concepts • Location of high-level radioactive waste packaging • Waste package designs • Transportation impact analyses • Role of waste storage in operations of the waste management system • Licensing impacts of an MRS facility • System reliability
Nuclear Waste Management Systems Issues Related to Transportation Cask Design: At-Reactor Spent Fuel Storage, Monitored Retrievable Storage and Modal Mix (Hoskins 1990, all)	
Provides the State of Nevada evaluation of the DOE MRS proposal and the Tennessee studies and position in response.	Addresses the DOE MRS proposal, which evaluated the option of implementing an integral MRS facility as part of a waste management system and the option of "no-MRS facility" as part of the waste management system. The criteria for the evaluation included health and safety, economic, environmental, political (for example, acceptability, public confidence, local and state attitudes), social (for example, fears and anxieties), fairness (for example, equity, intergenerational, utilities/ratepayer, liability, geographic, interutility, and government-utility), repository scheduling, and flexibility (technical and institutional factors).

Table 7-1. Documents that address storage of spent nuclear fuel and high-level radioactive waste[a] (page 3 of 4).

Title and scope of storage analysis	Environmental and other considerations
Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (DOE 1995a, all)	
Analyzes transportation and centralized interim storage of existing and projected inventories of DOE spent nuclear fuel (including naval spent nuclear fuel) at one site. Considers five interim storage sites (Hanford, INEEL, ORR, SRS, and the Nevada Test Site).	Focuses on key discriminator disciplines at each of the five sites, including socioeconomics, utilities (electricity), materials and waste management, occupational and public health and safety (radiation effects and accidents), transportation, and uncertainties and conservatism. Discusses cumulative impacts and impacts of no action. Does not provide detailed discussions of land use, cultural resources, aesthetic/scenic resources, geologic resources, air quality, water resources, ecological resources, noise, and utilities and energy because there would be small impacts for these areas that would be indistinguishable among the alternatives.
Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DOE 1996c, all)	
Evaluates a proposal to manage FRR spent nuclear fuel. Evaluates a management alternative for acceptance and management of FRR spent fuel in the United States that includes regionalized storage at SRS, INEEL, Hanford, ORR, and the Nevada Test Site. Basic implementation components of the proposal include policy duration, financing arrangements, amount of FRR spent fuel, location for taking title to FRR spent fuel, marine transport, ports of entry, ground transport, FRR spent fuel management sites, and storage technologies.	Analyzes impacts from policy considerations, marine transport, port activities, ground transport, and fuel management sites. More specifically, for fuel management sites, analyzes impacts for occupational and public health and safety, waste management, cumulative impacts, mitigation measures, and environmental justice. Covers impacts for land use, socioeconomics, cultural resources, aesthetics, scenic resources, geology, water resources, air quality, ecology, noise, utilities and energy, and waste management in general.
Final Waste Management Programmatic Environmental Impact Statement For Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DOE 1997b, all)	
Evaluates programmatic alternatives for managing various DOE wastes including HLW. Regionalized and centralized storage are among the management options evaluated. Under the regionalized alternatives, canisters from West Valley would be transported either to SRS or to Hanford, and HLW canisters would continue to be stored at Hanford, SRS, and INEEL until acceptance at the geologic repository. Under the centralized storage alternative, canisters would be transported from West Valley, INEEL, and SRS to Hanford, where they would be stored until acceptance at a geologic repository.	Describes regionalized and centralized sites based on available site-specific data and existing and planned storage facilities for HLW canisters. Impacts evaluated include health risks (includes transportation), air quality, water resources, ecological resources, economics, population, environmental justice, land use, infrastructure, cultural resources, and costs.

Table 7-1. Documents that address storage of spent nuclear fuel and high-level radioactive waste[a] (page 4 of 4).

Title and scope of storage analysis	Environmental and other considerations
Environmental Report for the Private Fuel Storage Limited Liability Company's (PFS) Proposed Independent Spent Fuel Storage Installation (ISFSI) License Application (NRC 1997b, all)	
Evaluates the impacts of a privately owned dry fuel storage facility proposed to be built in western Utah on the Skull Valley Goshute Indian Reservation. The facility would receive and store as much as 40,000 MTHM from several commercial nuclear reactor plants. The NRC has initiated development of a Draft EIS to support its licensing process for this facility. A scoping meeting was conducted on June 2, 1998, in Salt Lake City (transcripts of the meeting are available at the NRC web site: *http://www.nrc.gov/OPA/reports*).	Provides detailed descriptions and environmental impact analyses associated with construction and operation of the site and transportation corridors for geography, land use, and demography; ecological resources; climatology and meteorology (including air quality); hydrological resources; mineral resources; seismology; socioeconomics (including environmental justice analysis); noise and traffic; regional historic and cultural resources; scenic and natural resources; background radiological characteristics; and transportation (radiological and nonradiological impacts). Addresses installation siting and design alternatives based on several specific evaluation criteria (geography and demography; ecology; meteorology; hydrology; geology; regional historic/archaeological/architectural/scenic, cultural/natural features; noise; radiological characteristics).
Centralized Interim Storage Facility Topical Safety Analysis Report (DOE 1998p, all)	
Analyzes an above-ground temporary storage facility for up to 40,000 MTHM of commercial reactor spent nuclear fuel. The non-site-specific analysis concludes that DOE could construct and operate the commercial interim storage facility in a manner that protects public health and safety.	Describes generic site characteristics and design criteria developed to bound, to the extent possible, site-specific values once a CISF is selected. Generic site characteristics include meteorology, surface hydrology, geology, and seismology. Principal design parameters evaluated for normal and accident conditions include type of fuel, storage systems, fuel characteristics, tornado (wind and missile load), straight wind, floods, precipitation, snow and ice, seismicity (ground motion and surface faulting), volcanic eruption (ash fall), explosions, aircraft impact, proximity to uranium fuel cycle operations, ambient temperature, solar load, confinement, radiological protection, nuclear criticality, decommissioning, materials handling, and retrieval capability.

a. Abbreviations: ISFS = independent spent fuel storage; ORR = Oak Ridge Reservation; MRS = monitored retrievable storage; TVA = Tennessee Valley Authority; INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; FRR = Foreign Research Reactor; HLW = high-level radioactive waste; MTHM = metric tons of heavy metal; NRC = U.S. Nuclear Regulatory Commission; CISF = centralized interim storage facility.

INSTITUTIONAL CONTROL

Institutional control implemented by commercial utilities and DOE provides monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements. Having attained this goal, institutional control ensures the maintenance of incurred doses as low as reasonably achievable, taking social and economic factors into account. Because the future course of action taken by the Nation and by commercial utilities would be uncertain if Yucca Mountain were not recommended as a repository site, the continued storage analysis evaluated two hypothetical scenarios with different assumptions about institutional control to bound potential environmental impacts.

The assumption for Scenario 1 is that DOE and commercial utilities would maintain institutional control of the storage facilities to ensure minimal releases of contaminants to the environment for at least 10,000 years.

Scenario 2 assumes no effective institutional control after approximately 100 years. DOE based the choice of 100 years on a review of generally applicable U.S. Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), U.S. Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and the National Research Council report on standards for the proposed Yucca Mountain Repository (National Research Council 1995, page 106), which generally discount the consideration of institutional control for longer periods in performance assessments for geologic repositories. Assuming no effective institutional control after 100 years provides a consistent analytical basis for comparing the No-Action Alternative and the Proposed Action.

For consistency, the No-Action analysis considered the same spectrum of environmental impacts as the analysis of the Proposed Action. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely and the uncertainties typical in predictions of the outcome of complex physical and biological phenomena over long periods, DOE decided to focus the No-Action analysis on the short- and long-term health and safety of workers and members of the public.

To ensure a consistent comparison with the Proposed Action for the cumulative effects analysis, the analysis included the impacts of the continued storage of spent nuclear fuel and high-level radioactive waste in excess of 70,000 metric tons of heavy metal (MTHM). This additional material, with the 70,000 MTHM under the Proposed Action (collectively called Module 1), includes 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste.

In view of the almost unlimited possible future states of society and the importance of these states to future risk and dose, the National Research Council recommended the use of a particular set of assumptions about the biosphere (for example, how people get their food and water and from where) for compliance calculations such as those performed to evaluate long-term repository performance. Further, the National Research Council recommended the use of assumptions that reflect current technologies and living patterns (National Research Council 1995, page 122). For consistency with the methods used to analyze environmental impacts from the proposed repository, the No-Action analysis selected current technologies and living patterns for the long-term impact evaluation, even though they might not represent an accurate prediction of future conditions.

The No-Action Alternative differs from the Proposed Action in that it would affect the 72 commercial and 5 DOE facilities and their surrounding environments as well as the Yucca Mountain site. The commercial and DOE sites would experience long-term impacts that the Yucca Mountain site would not.

Under Scenario 1, 77 sites around the country would store spent nuclear fuel and high-level radioactive waste. For this scenario, the analysis assumed that institutional control for at least 10,000 years would ensure regular maintenance and continuous monitoring at the facilities, which would safeguard the health and safety of facility employees, surrounding communities, and the environment. All maintenance, including routine industrial maintenance and maintenance unique to a nuclear materials storage facility, would be performed under standard operating procedures or best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. With institutional control, the facilities would be maintained to ensure that workers and the public received adequate protection in accordance with current Federal regulations such as 10 CFR Part 20 and Part 835 and DOE Order requirements (see Chapter 11).

In addition, the Scenario 1 analysis assumed that storage facilities would undergo replacement every 100 years and would undergo major repairs halfway through the first 100-year cycle, because the storage facilities at any site would be built for a facility life of less than 100 years. (Federal regulations [10 CFR 72.42(a)] require license renewal every 20 years.) Figure 7-1 shows facility timelines for Scenarios 1 and 2.

DOE and commercial organizations intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, to provide a basis for evaluating the upper limits of potential adverse human health impacts, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years. Therefore, after about 100 years and up to 10,000 years, the scenario assumes that spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial sites and 5 DOE sites would begin to deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually be released to the environment, contaminating the local soil, surface water, and groundwater. Appendix K contains the details of this long-term analysis.

For this environmental impact statement (EIS), DOE performed analyses to 10,000 years from the present. To parallel the repository analysis, the No-Action analysis considered both short- and long-term impacts. Short-term impacts would be those experienced during about the first 100 years, and long-term impacts would be those experienced during the remaining 9,900 years. Short-term impacts would be the same under Scenarios 1 and 2 because both scenarios assume institutional control during this period. The short-term No-Action Alternative impacts include those resulting from the termination of activities at Yucca Mountain and decommissioning and reclamation of the site, so there would be no long-term impacts at the Yucca Mountain site. In addition, the short-term No-Action Alternative impacts at Yucca Mountain would be the same for both scenarios.

Impacts at the 77 sites after approximately 100 years (long-term) under Scenario 1 primarily would affect facility workers. Long-term impacts at the storage sites after approximately 100 years under Scenario 2 would affect only members of the public because the facility would close and there would be no workers (Scenario 2 assumes no effective institutional control after about 100 years).

To permit a comparison of both short- and long-term impacts from the construction, operation and monitoring, and eventual closure of a proposed repository at Yucca Mountain and from the No-Action Alternative, DOE took care to maintain as much consistency as possible in the methods used to analyze

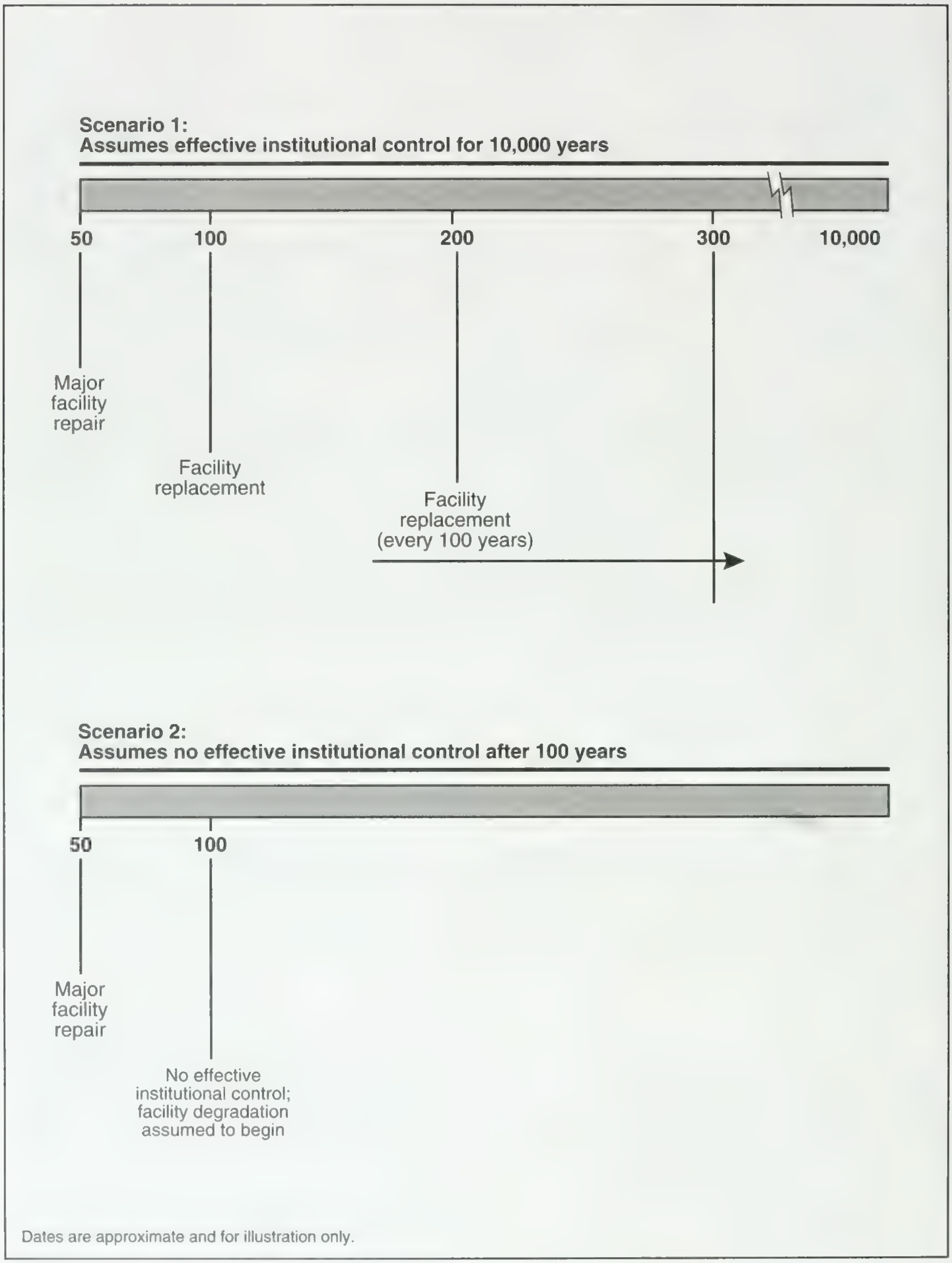


Figure 7-1. Facility timeline assumptions for No-Action Scenarios 1 and 2.

environmental impacts from the proposed repository and the No-Action Alternative. Important consistencies include the following:

- Identical spent nuclear fuel and high-level radioactive waste inventories:
  - Proposed Action: 63,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of high-level radioactive waste, and 50 MTHM of surplus weapons-usable plutonium
  - Module 1: Proposed Action materials plus an additional 42,414 MTHM of commercial spent nuclear fuel, 167 MTHM of DOE spent nuclear fuel, and 13,965 canisters of high-level radioactive waste resulting in a total of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, 22,280 canisters of high-level radioactive waste, and 50 MTHM of surplus plutonium (see Appendix A, Figure A-2)

> **DEFINITION OF METRIC TONS OF HEAVY METAL**
>
> Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

- Identical evaluation periods of 100 years (short-term impacts) and of 100 to 10,000 years (long-term impacts)
- Consistent spent nuclear fuel and high-level radioactive waste corrosion and dissolution models
- Identical radiation dose and risk conversion factors
- Similar assumptions regarding the habits and behaviors of future population groups (that is, they would not be greatly different from those of populations today)

7.1 Short-Term Impacts in the Yucca Mountain Vicinity

Chapter 3, Section 3.3, discusses the conditions at the sites that formed the basis for identifying potential impacts associated with the No-Action Alternative. The conditions include the relatively small incremental impacts resulting from continued characterization activities in the Yucca Mountain vicinity until 2002. Under the No-Action Alternative, DOE would terminate characterization activities at the site and would begin site decommissioning and reclamation. Decommissioning and reclamation would include dismantling and removing structures, shutting down some surface facilities, and rehabilitating land disturbed during characterization activities. DOE would salvage usable equipment and materials. Drill holes would be sealed, subsurface drifts and rooms would be left in place, and the portals would be gated. The piles of excavated rock from the tunnel would be landscaped. Areas disturbed by surface studies or used as laydown yards, borrow areas, or the like would be restored. Holding ponds would be backfilled or capped. DOE would not remove foundations or infrastructure such as access roads, parking lots, and sewage systems. The analysis assumed that reclamation activities would take about 1 year. Chapter 2, Section 2.2, describes the No-Action Alternative at Yucca Mountain.

The short-term impacts from reclamation of the Yucca Mountain site would occur regardless of the No-Action Alternative scenario and would be the same for both scenarios.

7.1.1 LAND USE AND OWNERSHIP

Land ownership and control could revert to the original controlling authority.

Under the No-Action Alternative, decommissioning and reclamation would begin as soon as practicable at the Yucca Mountain site, which DOE anticipates would happen in 2002. No new land would be required to support the decommissioning and reclamation activities. Because DOE stored topsoil and material from the mountain during site characterization, it would need no additional land to provide soil for reclaiming the material taken from the mountain or for backfilling holding ponds or the reclamation of other previously disturbed areas. Therefore, the No-Action Alternative would not require the disturbance of additional land at the site. The disturbed land would be restored to its approximate preconstruction condition about 100 years earlier than would occur under the Proposed Action.

7.1.2 AIR QUALITY

Transient effects on air quality would result from the exhausts of the heavy equipment that DOE would use during the decommissioning and reclamation activities that the Department expects to complete over a 1-year period. Recontouring and revegetation activities would generate dust containing particulate matter less than 10 micrometers in diameter (PM_{10}). Impacts on air quality would be no greater than those associated with the construction phase during the Proposed Action for each of the thermal load scenarios, as discussed in Chapter 4, Section 4.1.2, because less land would be disturbed by fewer vehicles during decommissioning and reclamation activities. Because the air quality impacts described in Section 4.1.2 represent a small fraction of the regulatory limit (that is, less than 10 percent of regulatory limits), the No-Action Alternative would not adversely affect air quality.

7.1.3 HYDROLOGY

7.1.3.1 Surface Water

The No-Action Alternative would not adversely affect surface water. During decommissioning and reclamation, adherence to such best management practices as stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion. To prevent contamination from heavy equipment, workers would monitor the equipment for leaks and would contain and clean up inadvertent spills of industrial fluids following established spill prevention and cleanup plans. DOE would dismantle and remove all surface structures, equipment, and building materials (DOE 1995g, page 2-8), including such items as fuel storage tanks and facilities where petroleum products or potentially hazardous materials like paints and solvents were stored before removal. Hazardous materials removed or generated during decommissioning would be taken from the site and reused, recycled, or disposed of in accordance with applicable regulations (DOE 1995g, page 2-8). After closure, contaminant sources would be gone so there could be no movement of contaminants to surface water (see Chapter 4, Section 4.1.12.2, for details). The analysis assumed that reclamation activities would be complete about 1 year after the decision to implement the No-Action Alternative, which DOE anticipates would occur in 2002.

As part of the reclamation activities, DOE would recontour the landscape to match its precharacterization conditions, ensuring natural drainage patterns. Because the North and South Portal ramps of the Exploratory Studies Facility slope upward to prevent ingress of surface water, they would not appreciably affect natural drainage patterns. Seeding and other erosion control measures would ensure normal

infiltration rates. Under the No-Action Alternative, DOE anticipates that the restoration of natural drainage patterns would be complete about 100 years earlier than under the Proposed Action.

7.1.3.2 Groundwater

The No-Action Alternative would not adversely affect groundwater. DOE would remove all sources of contaminants (such as petroleum products and potentially hazardous materials like paints and solvents) from the site. The entrance ramps of the open portals of the Exploratory Studies Facility are sloped such that surface water would drain away from the openings. During reclamation activities (which would take about 1 year), the Exploratory Studies Facility portals would be closed.

7.1.4 BIOLOGICAL RESOURCES AND SOILS

Approximately 1.4 square kilometers (350 acres) of habitat has been disturbed; most of the disturbance is associated with the Exploratory Studies Facility, the storage area for the material removed from the tunnel, the topsoil storage area, borrow pits, boreholes, trenches, and roads. Site reclamation activities would include removal of structures and equipment, soil stabilization, and revegetation plantings at many of the disturbed sites (DOE 1995g, all). Proper soil stabilization would prevent erosion. Once the area was reclaimed, stabilized, and planted with natural vegetation, and once activities at the site decreased, the precharacterization floral and faunal diversity would begin to reestablish itself. Some animal species could take advantage of abandoned tunnels for shelter; for example, the tunnels could provide attractive roosting and nesting sites for bats. Individuals of the threatened desert tortoise species could be adversely affected during the decommissioning and reclamation of the site. The No-Action Alternative would have no other adverse effects on biological resources or soils. In addition, the reclamation would result in the restoration of 1.4 square kilometers of habitat.

7.1.5 CULTURAL RESOURCES

The potential effects of other uses of the Yucca Mountain site on cultural resources are not known because no other uses have been identified; therefore, no assessment of the effects is possible. If the land were to revert to the previous controlling authorities, the stewardship of cultural resources would be consistent with applicable policies, regulations, and procedures.

Because no additional land would be required for decommissioning and reclamation activities, disturbances to cultural resources on undisturbed land in the area would be unlikely. Leaving access roads in place could have an adverse impact on cultural resources if the site boundaries are not secure. Preserving the integrity of important archaeological sites and resources important to Native Americans could be difficult if the public had increased access to the site.

7.1.6 SOCIOECONOMICS

Many of the repository workers would shift to decommissioning and reclamation tasks. An average annual workforce of about 1,800 would complete decommissioning and reclamation tasks at the repository site. After decommissioning and reclamation, the Nevada Test Site would assume the responsibility of preventing inadvertent entry to the North and South Portal areas. A small workforce would protect these areas after reclamation.

After the 1-year decommissioning and reclamation period, the decommissioning and reclamation workforce, along with about 1,400 project-related workers employed away from the repository site, would lose their jobs. The total direct employment reduction, therefore, would be about 3,200 at the completion

of decommissioning and reclamation. For every direct job lost, about 0.46 indirect job would also be lost (TRW 1999a, all). *Indirect jobs* are those created as a result of direct employment; examples would include jobs that provide essential services, such as medical and police protection, to the individuals directly employed by the project. Therefore, the overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the region of influence.

As stated in Chapter 3, Section 3.1.7.1, approximately 80 percent of workers at the Yucca Mountain site reside in Clark County, 19 percent reside in Nye County, and less than 1 percent reside in Lincoln County or elsewhere (TRW 1999n, all). Thus, ending characterization activities would have the greatest potential impact in Clark County. If the region (Clark, Lincoln, and Nye Counties) continued to add about 2,800 new jobs every month, impacts would be offset by continued economic growth (Chapter 3, Section 3.1.7.5). Therefore, terminating site characterization activities would have a very minor impact on socioeconomic factors.

The cessation of repository activities would result in the loss of payments by the Federal Government in lieu of taxes. Nye County collects most of the monies associated with the repository project. The 1997 Nye County budget totaled approximately $83.8 million (county government and school district). During the same period, Nye County received approximately $5.4 million as payment in lieu of taxes dollars (TRW 1999n, all).

7.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY FOR ROUTINE OPERATIONS

Chapter 2, Section 2.2.1, describes the actions DOE would take at Yucca Mountain under the No-Action Alternative. During the decommissioning and reclamation phase, these actions would expose workers and members of the public to the nonradioactive and radioactive contaminants discussed in Chapter 4, Sections 4.1.2.2, 4.1.3.1, and 4.1.7.2. In addition, these actions would place workers at risk for occupational (industrial safety) incidents such as illnesses, injuries, and fatalities. Appendix F, Section F.2.2.2, describes the statistics used to estimate health and safety impacts from industrial safety incidents. Because the activities that workers would perform under the No-Action Alternative would involve risks similar to those during the construction and closure phases of the Proposed Action, DOE used these statistics to estimate worker health impacts.

Worker exposures to nonradioactive contaminants of concern (diesel engine exhaust and mineral dusts containing respirable erionite and crystalline silica) during decommissioning and reclamation activities would be limited by administrative and engineering means. Exposures would be maintained below occupational levels that could affect worker health adversely, as specified by the Occupational Safety and Health Administration and detailed in the project health and safety plan (TRW 1999t, all). Accordingly, worker exposures to nonradioactive contaminants would not contribute to adverse health impacts.

Tables 7-2 and 7-3 summarize the estimated total impacts from workplace industrial hazards and from radiological exposure, respectively, for reclamation activities. Table 7-4 summarizes impacts to members of the public.

Table 7-2. Estimated industrial safety impacts for surface and subsurface workers during decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Total recordable cases	Lost workday cases	Fatalities
Involved workers[b]	85	41	0
Noninvolved workers[c]	14	7	0
Totals	**99**	**48**	**0**

a. Source: For impact statistics, Appendix F, Table F-2 (for construction and closure, which are the same).
b. Involved worker population of about 1,400 surface and subsurface workers.
c. Noninvolved worker population of about 440 management and administrative personnel.

Table 7-3. Estimated radiation doses and health effects for surface and subsurface workers from decommissioning and reclamation activities at Yucca Mountain.[a,b]

Group	Maximally exposed individual (millirem)	LCF[c] risk to the maximally exposed individual	Collective worker dose[d] (person-rem)	LCF[e]
Involved workers[f]	150	0.00006	77	0.030
Noninvolved workers[g]	120	0.00005	12	0.0050
Totals	**NA**[h]	**NA**	**89**	**0.035**

a. Source: Appendix F, Table F-4 (intermediate thermal load scenario, dual-purpose canister packaging option); data adjusted for 1 year of activity. Values represent most probable (intermediate range) impacts for thermal load and packaging scenarios analyzed.
b. The impacts listed would be the result of 1 year of decommissioning and reclamation activities; adapted from construction phase impacts. Worker doses would result from exposure to radon and other terrestrial radiation sources.
c. LCF = latent cancer fatality.
d. The calculation of doses and health effects assumes no worker rotation for exposure control purposes.
e. Expected number of cancer fatalities for populations. Based on a risk of 0.0004 latent cancer per rem for workers (NCRP 1993b, page 112).
f. Involved worker population of about 1,400 surface and subsurface workers.
g. Noninvolved worker population of about 440 management and administrative personnel.
h. NA = not applicable.

Table 7-4. Estimated public radiation doses and health effects from decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Maximally exposed individual (millirem per year)	Annual increase in risk for contracting an LCF[b]	Collective public dose[c] (person-rem)	LCF
Public	0.12	0.00000006	0.64	0.00032

a. The impacts listed would be the result of 1 year of decommissioning and reclamation activities.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993b, page 112), and a life expectancy of 70 years for a member of the public.
c. The collective dose to 28,000 individuals living within 80 kilometers (50 miles) would be from radon emissions from the subsurface facilities.

Involved and noninvolved worker group losses under the No-Action Alternative would be about 100 total recordable cases of injury and illness, resulting in about 48 lost workday cases and no fatalities (Table 7-2).

Worker population radiation exposures during the year of decommissioning and reclamation activities would result from exposure to radioactive radon decay products that would emanate from the tunnel's rock matrix and from ambient radiation. Exposures to the subsurface workers could result in a collective dose of about 77 person-rem (Table 7-3). Doses to the maximally exposed involved subsurface worker and noninvolved worker could be as high as about 150 millirem and 120 millirem, respectively.

Public radiation exposures during decommissioning and reclamation would result from radon emissions from the subsurface facilities. These exposures could result in an annual dose to the hypothetical maximally exposed individual, about 20 kilometers (12 miles) south of the repository, of 0.12 millirem. The maximum collective dose to the projected population of 28,000 within 80 kilometers (50 miles) would be about 0.64 person-rem (Table 7-4).

The increased likelihood of the maximally exposed individual worker experiencing a latent cancer fatality would be very small (0.0005 to 0.0006). The latent cancer fatality incidence value would be small in comparison to the overall impacts for the Proposed Action (about 1 percent).

7.1.8 ACCIDENTS

Under the No-Action Alternative, DOE would not ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain, and there would be only limited quantities of nonradioactive hazardous or toxic substances. Therefore, accident impacts would be limited to those from traffic and industrial hazards.

Table 7-2 lists impacts from industrial accident scenarios and Section 7.1.14 discusses impacts from traffic accident scenarios.

7.1.9 NOISE

Noise levels during decommissioning and reclamation activities would be no greater than those of site characterization activities. After the decommissioning and reclamation activities were complete, ambient noise would return to levels consistent with a desert environment where natural phenomena account for most background noise (see Chapter 3, Section 3.1.9.1). The No-Action Alternative would not adversely affect the noise levels of the Yucca Mountain region.

7.1.10 AESTHETICS

Site decommissioning and reclamation activities would improve the scenic value of the site. Borrow pits and holding ponds would be filled or graded, stabilized, and revegetated. Most structures would be removed down to their foundations. The North and South Portals would be gated. The surface area of these disturbed areas would represent a small fraction of the total surface area of the repository site and, therefore, would be unlikely to cause adverse impacts to the overall scenic value of the area. Under the No-Action Alternative, the site would be returned to a state as close as possible to the predisturbed state; therefore, DOE would not expect adverse impacts to the scenic value of the area. Site restoration would occur about 100 years earlier than under the Proposed Action.

7.1.11 UTILITIES, ENERGY, AND MATERIALS

Decommissioning and reclamation activities would consume electricity, diesel fuel, and gasoline. Much equipment and many materials would be salvaged and recycled. DOE would recycle buildings as practicable. After the site closed, minimal surveillance activities would require some electricity and gasoline. If the site were abandoned after 100 years, no utilities or energy resources would be consumed. The No-Action Alternative would not adversely affect the utility, energy, or material resources of the region.

7.1.12 WASTE MANAGEMENT

The decommissioning and reclamation of the Yucca Mountain site would generate some waste requiring disposal, including sanitary sewage, sanitary and industrial solid waste, small amounts of demolition debris, and very small amounts of hazardous waste. DOE would dispose of the wastes as it has during the site characterization activities.

DOE would minimize waste generation by salvaging most of the equipment and many materials and redistributing them to other DOE sites or selling them at public auction. Remaining chemical supplies would be redistributed through the DOE excess program, which collects equipment and materials no longer in use for reassignment to other DOE sites or Federal facilities, donation to state governments, or sale to the public. DOE would preserve, rather than demolish, certain facilities that could be useful in the future, such as the electrical distribution and water supply systems. Sanitary sewage would be disposed of in the onsite septic system. At the end of reclamation activities, DOE would cap the inlets to the septic

system and leave the system in place. DOE would dispose of sanitary and industrial solid waste and demolition debris in existing Nevada Test Site landfills, where disposal capacity would be available for about 70 years (DOE 1995f, page 8).

7.1.13 ENVIRONMENTAL JUSTICE

An examination of analyses from other technical disciplines associated with terminating characterization and construction activities at Yucca Mountain and decommissioning and reclaiming the site shows no potential for large impacts in areas other than cultural resources and socioeconomics. The cultural resources analysis identified the possibility that increased public access (if roads were left open and site boundaries were not secure) could threaten the integrity of archaeological sites and resources important to Native Americans. The socioeconomic analysis identified a potential loss of as many as 4,700 jobs.

Disproportionate impacts to minority or low-income populations from potential job losses would be unlikely because the workforce would not include a disproportionate number of minority and low-income workers.

7.1.14 TRAFFIC AND TRANSPORTATION

Fatalities from project-related traffic would be unlikely during decommissioning and reclamation. As a gauge of the probability of 1 fatality, decommissioning and reclamation activities would require about 1 year to complete, or about one-sixth to one-fifteenth of the time to close the repository. The analysis in Chapter 6 estimated 1.2 fatalities from traffic accidents during repository closure, so an estimated 0.2 traffic fatality would be likely during decommissioning and reclamation.

7.1.15 SABOTAGE

There would be no nuclear materials at the Yucca Mountain site, so sabotage concerns would not be pertinent.

7.2 Commercial and DOE Sites

This section analyzes short- and long-term impacts of continued storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites for 10,000 years (the period considered for the Proposed Action). The analysis includes No-Action Scenarios 1 and 2.

The following paragraphs discuss short-term impacts under No-Action Scenario 1. Because the analysis assumed that all sites would maintain institutional control for the first approximately 100 years, the short-term impacts for Scenarios 1 and 2 would be the same. For consistency with the Proposed Action, this analysis assumed the No-Action scenarios would begin in 2002. This analysis considered the Idaho National Engineering and Environmental Laboratory to be a site for naval spent nuclear fuel because the Laboratory stores such fuel.

Under the No-Action Alternative, commercial utilities would manage their spent nuclear fuel at 72 facilities. DOE would manage its spent nuclear fuel and high-level radioactive waste at five facilities (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only) the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site). The No-Action analysis evaluated the DOE spent nuclear fuel and high-level radioactive waste at existing sites or at sites where existing Records of Decisions have placed or will place these materials. For example, the Record of Decision (60 *FR* 18589, April 12, 1995) for the *Final Supplemental Environmental Impact Statement, Defense Waste Processing Facility* (DOE 1994a, all)

decided to complete construction and operate the Defense Waste Processing Facility and associated facilities at the Savannah River Site to pretreat, immobilize, and store high-level radioactive waste. Similarly, the *Hanford Site Final Environmental Impact Statement for the Tank Waste Remediation System* (DOE 1996d, all) identified as the preferred alternative *ex situ* vitrification of high-level radioactive waste with onsite storage until final disposition in a geologic repository. For DOE spent nuclear fuel, the Record of Decision (60 *FR* 28680, June 1, 1995) for the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995a, all) decided that Hanford production reactor fuel would remain at the Hanford Site; aluminum-clad fuel would be consolidated at the Savannah River Site; and non-aluminum-clad fuels (including spent nuclear fuel from the Fort St. Vrain reactor and naval spent nuclear fuel) would be transferred to the Idaho National Engineering and Environmental Laboratory. Therefore, the analysis evaluated DOE aluminum-clad spent nuclear fuel at the Savannah River Site and DOE non-aluminum-clad fuel at the Idaho National Engineering and Environmental Laboratory; most of the Fort St. Vrain spent nuclear fuel at the Colorado generating site; and high-level radioactive waste at the generating sites (the West Valley Demonstration Project, the Idaho National Engineering and Environmental Laboratory, the Hanford Site, and the Savannah River Site).

The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored in a condition ready for shipment to a repository. The amount (inventory) of spent nuclear fuel and high-level radioactive waste considered in this analysis would be the same as that for the Proposed Action 70,000 metric tons consisting of 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of solidified high-level radioactive waste, and 50 metric tons of surplus plutonium. In addition, DOE recognizes that more than 107,000 MTHM of commercial and DOE spent nuclear fuel and more than 22,000 canisters of high-level radioactive waste could require storage if a disposal site is not available. Section 7.3 describes the assumptions and analytical methods used to estimate impacts for the total projected inventory of spent nuclear fuel and high-level radioactive waste, referred to as Inventory Module 1, and evaluates the potential impacts of the continued storage of the total projected inventory of commercial and DOE spent nuclear fuel and high-level radioactive waste.

Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection from the environment for packages containing spent nuclear fuel and high-level radioactive waste. Because it has not selected specific designs for most locations, DOE selected a representative range of commercial and DOE designs for analysis, as described in the following paragraphs. In addition, for purposes of analysis, the No-Action Alternative assumed that the commercial and DOE sites have sufficient land to construct the initial and replacement storage facilities and that the initial construction of all dry storage facilities would be complete and the facilities filled by 2002.

Spent Nuclear Fuel Storage Facilities

Most commercial sites currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor sites. Because they have inadequate storage space, some commercial sites have built what are called *independent spent fuel storage installations,* in which they store dry spent nuclear fuel above ground in metal casks or in welded canisters inside reinforced concrete storage modules. Other commercial sites plan to build independent spent fuel storage installations so they can proceed with the decommissioning of their nuclear plants and termination of their operating licenses (for example, the Rancho Seco and Trojan plants). Because commercial sites could elect to continue operations until their fuel pools became full and then cease operations, the EIS analysis initially considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However,

dry storage is almost certainly the preferred option for long-term spent fuel storage at commercial sites for the following reasons (NRC 1996, pages 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be stored in dry configurations in independent spent fuel storage installations at existing locations (Figure 7-2 is a photograph of the independent spent fuel storage installation at the Calvert Cliffs nuclear electricity-generating site). This assumption includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluates the impacts of storing all commercial and most DOE spent nuclear fuel in horizontal concrete storage modules (Figure 7-3) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that spent nuclear fuel from both pressurized-water and boiling-water reactors would be stored in a dry storage canister inside the concrete storage module. Figure 7-4 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were maintained properly. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. In addition, the concrete storage module would provide protection from damage resulting from accidents such as aircraft crashes and from natural hazard phenomena such as earthquakes or tornadoes.

This analysis assumed that DOE would store dry spent nuclear fuel at the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain in stainless-steel canisters inside above-grade reinforced concrete storage modules. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial sites.

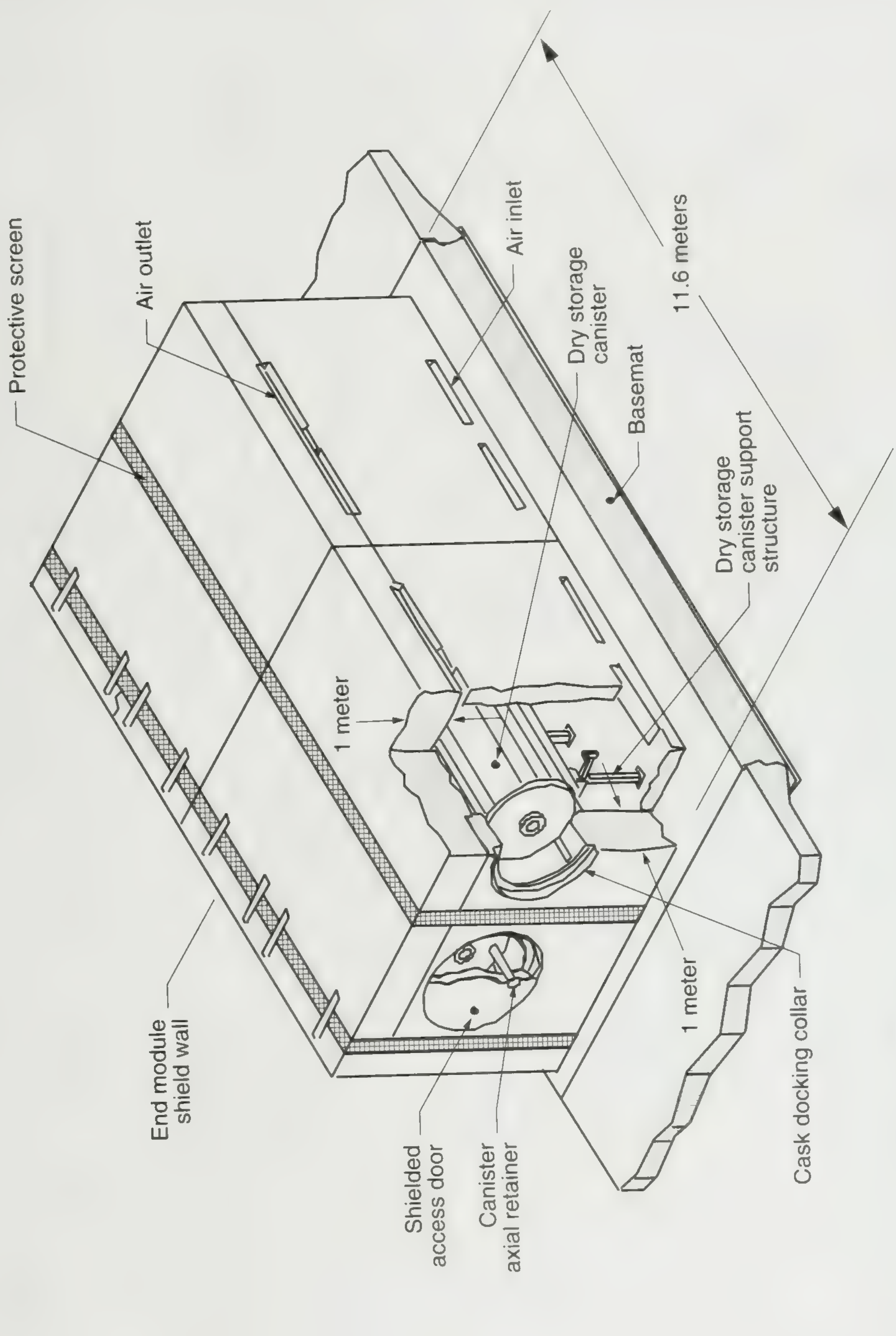
The analysis assumed that DOE would store spent nuclear fuel at Hanford in a dry cask in below-grade storage facilities. DOE would store Hanford N-Reactor fuel in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. The vaults would contain vertical storage tubes made of carbon steel. Each storage tube, which would hold two spent nuclear fuel canisters, would be sealed with a shield plug. DOE would cover the vaults with a structural steel shelter.

High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that DOE would store solidified high-level radioactive waste in dry below-grade, high-level radioactive waste storage facilities (Figure 7-5). At the West Valley Demonstration Project, the analysis assumed that DOE would use a dry storage system similar to a commercial independent spent nuclear fuel storage installation for high-level radioactive waste.

A high-level radioactive waste storage facility consists of four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a

Figure 7-2. Calvert Cliffs independent spent fuel storage installation and reactors.

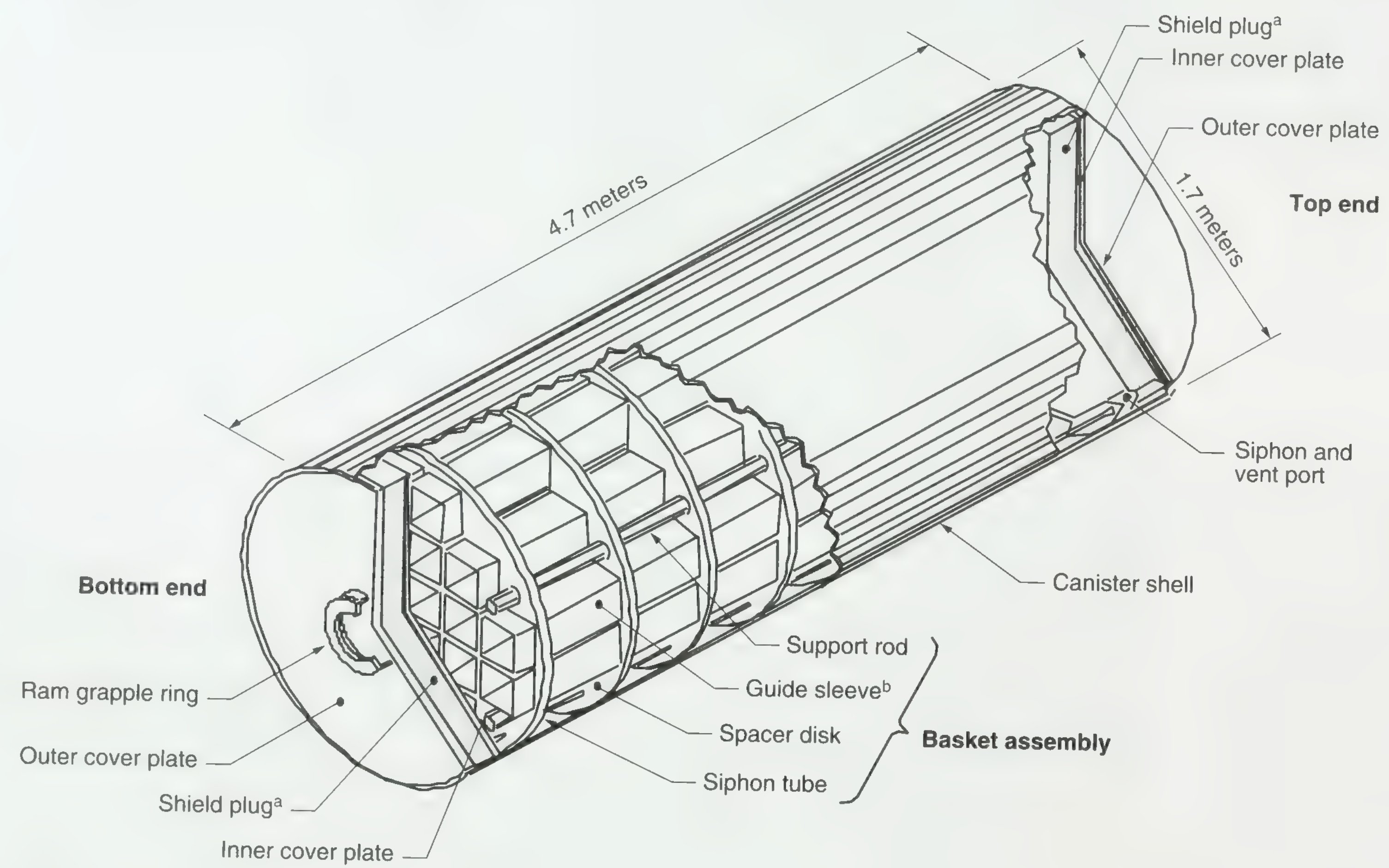


Source: Modified from Poe (1998a, page 1-2)

To convert meters to feet, multiply by 3.2808.

Note: Arrangement shown is a row of two storage modules with two canisters in each module.

Figure 7-3. Spent nuclear fuel concrete storage module.



All materials 304 stainless steel except as noted.

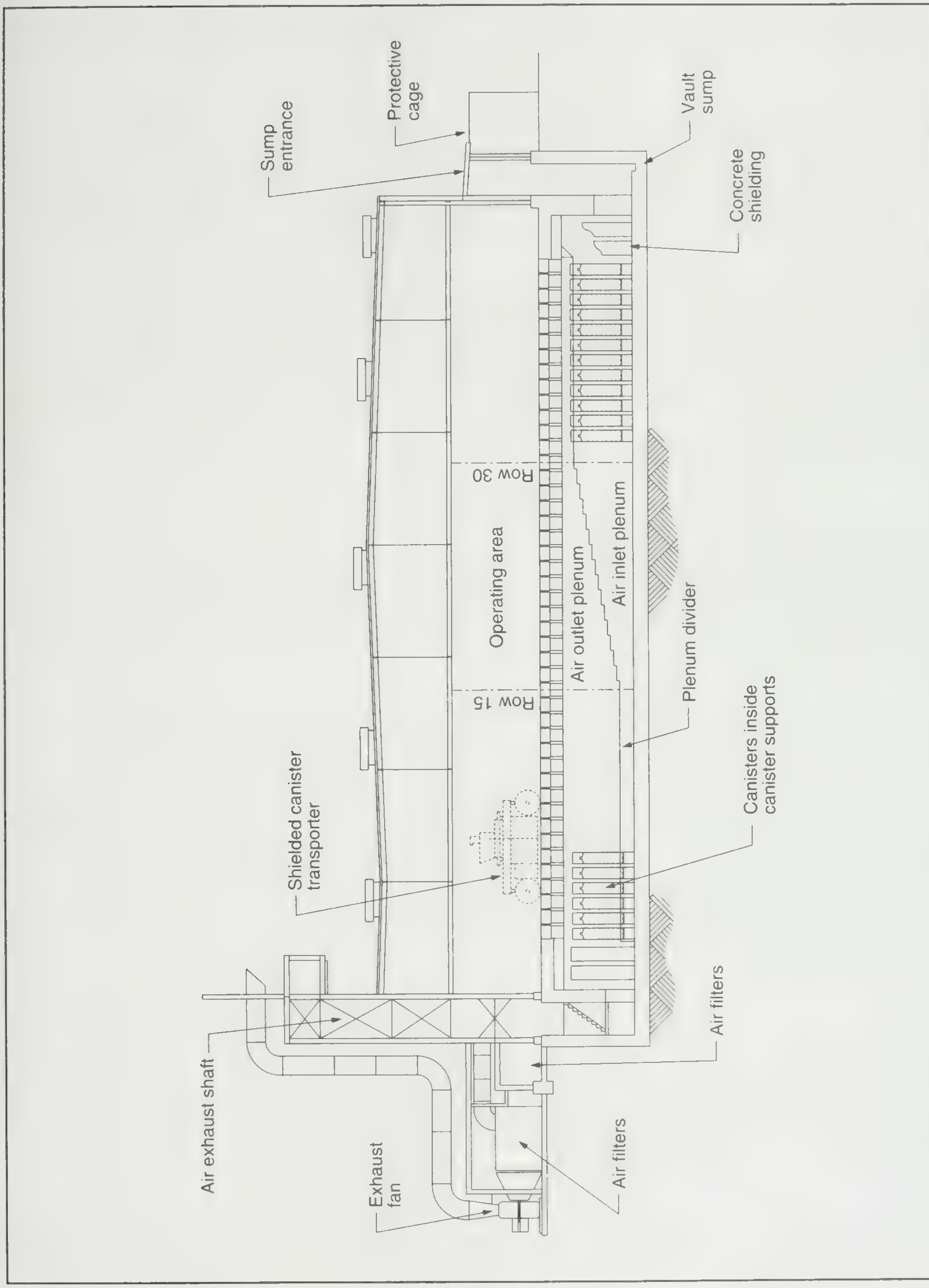
a. Shield plug would be lead.

b. Borated neutron absorber plate for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from Poe (1998a, page 1-5)

Figure 7-4. Spent nuclear fuel dry storage canister.



Source: Derived from Poe (1998a, pages 4-7, 4-8, and 4-11).

Figure 7-5. Conceptual design for solidified high-level radioactive waste storage facility.

concrete base mat. Space between the pipes is filled with overlapping horizontally-stepped steel plates that direct most of the ventilation air through the storage cavities.

The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment for as long as the facilities were maintained. The surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area would provide radiation shielding. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The storage facility's ventilation system would remove the heat of radioactive decay from around the canisters. The exhaust air could pass through high-efficiency particulate air filters before it discharged to the atmosphere through a stack. As an alternative, natural convection cooling without filters could be used. The oversized diameter of the pipe storage cavities would allow air to pass around each cavity.

7.2.1 NO-ACTION SCENARIO 1

Under Scenario 1, 72 commercial sites and 5 DOE sites would store spent nuclear fuel and high-level radioactive waste for 10,000 years. Institutional control, which would be maintained for the entire 10,000-year period, would ensure regular maintenance and continuous monitoring at these facilities that would safeguard the health and safety of facility employees, surrounding communities, and the environment. The spent nuclear fuel and immobilized high-level radioactive waste would be inert material encased in durable, robust packaging and stored in above- or below-grade concrete facilities. Release of contaminants to the ground, air, or water would not be expected during routine operations.

DOE and commercial utility workers would perform all maintenance including routine industrial maintenance and maintenance unique to a nuclear materials storage facility under standard operating procedures and best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. This analysis assumed that DOE would manage these facilities in accordance with Departmental rules (10 CFR Part 835) and Orders (see Chapter 11) and that commercial facilities would meet applicable environmental safety and health requirements. It also assumed that storage facilities would require replacement every 100 years and that they would undergo major repairs halfway through the first 100-year cycle. Chapter 2, Section 2.2, provides additional information pertaining to Scenario 1. The following sections treat short- and long-term impacts separately where appropriate.

7.2.1.1 Land Use and Ownership

The storage facilities for spent nuclear fuel and high-level radioactive waste would be at commercial and DOE sites. Facilities would require replacement every 100 years (beginning about 2110), which would occur on land immediately adjacent to the existing facilities. The land required for a storage facility typically would be a few acres, a small percentage of the land available at current sites. An environmental assessment of an independent spent fuel storage installation determined that operation of the facility would require no more land than it occupied (NRC 1991, page 20).

At the end of each 100-year cycle, a new facility constructed next to the old one would contain the spent nuclear fuel or high-level radioactive waste. The old facility would be demolished and the land reclaimed and maintained for the next 100 years. By alternating the facility between two adjacent locations, minimal land would be required.

Storage facilities would be on land owned by either DOE or a utility. Storage at these sites would be unlikely to affect land use and ownership.

7.2.1.2 Air Quality

As a part of routine operations, best management practices and effective monitoring procedures would ensure that any contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutant emissions and Part 50 for air quality standards). Therefore, the No-Action Alternative would not produce adverse impacts to air quality during routine operations.

The analysis assumed that the storage facilities would require complete replacement every 100 years. During the construction of the replacement facility, exhaust from construction vehicles would temporarily increase local levels of hydrocarbons, carbon monoxide, and oxides of nitrogen, but these and other atmospheric pollutants would be likely to remain within National Ambient Air Quality Standards (see Chapter 3, Table 3-5). Temporary increases in particulate matter would result from these construction activities. Mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. In addition, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Detrimental air quality impacts would be short-term, minimal, and transient.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements; these impacts were not included in the overall impact estimates. Long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

7.2.1.3 Hydrology

7.2.1.3.1 *Surface Water*

As part of routine operations, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent contaminant release, contaminants did not reach surface-water systems. Effective monitoring procedures would ensure that operation of the facility did not adversely affect surface waters and that no discharges would contaminate surface waters in excess of drinking water regulatory limits (40 CFR Part 141). Detention basins would capture all runoff, which would be monitored for contamination and treated, as necessary, before it was released to the environment. If the storage facility required active cooling systems, those systems would be designed to contain any inadvertent spill of operating fluids so they could not reach the environment. Therefore, No-Action Scenario 1 would be unlikely to produce adverse impacts to surface-water quality during routine operations.

During construction of the replacement storage facilities, adherence to stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion that could adversely affect surface-water quality. Surface-water runoff detention ponds would prevent eroded material from entering surface water systems. These erosion control practices would ensure minimal impacts to surface-water quality during construction. To prevent contamination from construction equipment, workers would monitor the equipment for leaks. Inadvertent spills of industrial fluids would be contained and cleaned up in accordance with established spill prevention and cleanup plans. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to surface-water quality during construction operations.

7.2.1.3.2 *Groundwater*

During routine operations, best management practices such as spill prevention and cleanup plans and procedures and effective monitoring procedures would ensure that inadvertent contaminant releases would not reach groundwater. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during routine operations.

The spent nuclear fuel storage facilities at the commercial sites would be surface structures with shallow foundations such that their construction would not disturb groundwater systems. Some DOE storage facilities would be subsurface structures for which construction might require minimal dewatering of the groundwater aquifer. However, the area occupied by the structure would be small in relation to the size of the aquifer, so no adverse impacts would be likely to result from dewatering activities.

Excavations would remove the soil buffer between surface activities and groundwater, increasing the likelihood of groundwater contamination from an inadvertent spill or leak of construction-related fluids (for example, diesel fuel, oil, hydraulic fluids). Construction activities would be as described above for surface water; thus, the penetration of spilled construction fluids to groundwater would be unlikely. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during construction operations.

7.2.1.4 Biological Resources and Soils

Impacts to biological resources or soils from the construction and operation of spent nuclear fuel and high-level radioactive waste storage facilities would be minimal. Heat from the storage modules would not affect nearby vegetation. The storage facilities would be fenced to keep wildlife out. However, some smaller animal species could take advantage of the warm air from storage facility vents in winter, and individual animals could receive adverse impacts, including death, from direct exposure to radiation. As the heat of radioactive decay decreased, these sites would become less attractive to animals seeking warm environments.

The storage facilities would have a minimal effect on the soil. Because the operating and decommissioned facilities would alternate between two locations, the amount of soil disturbed by construction would be very small. By adhering to best management practices and standard operating procedures, DOE expects that spills would be minimal. A spill would be contained and cleaned up immediately, thus minimizing the area of soil affected.

7.2.1.5 Cultural Resources

Replacement spent nuclear fuel and high-level radioactive waste storage facilities would generally be on undeveloped land in rural areas owned by DOE or the commercial utilities. The size of each facility and supporting infrastructure would be small enough to avoid known cultural resources. If construction activities uncovered previously unknown archaeological sites, human remains, or funerary objects, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources (see Chapter 11, Section 11.2.5, for details). Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to cultural resources during construction and operations.

7.2.1.6 Socioeconomics

Storage facilities for spent nuclear fuel and high-level radioactive waste would be at existing DOE and commercial sites. A staff of about eight workers (two individuals on duty per shift, 24 hours per day)

would monitor and maintain each facility (Orthen 1999, Table 2, page 4). The analysis assumed that facilities would require replacement every 100 years, and that there would be a major facility repair halfway through the first 100-year cycle. Facility replacement every 100 years would require approximately 40 workers for 2 years (Orthen 1999, Table 2 and Table 6). Major repairs halfway through the first 100-year cycle would require about 40 workers for 1 year (Orthen 1999, Table 2 and Table 6).

Each of the 77 sites that stores spent nuclear fuel or high-level radioactive waste employs monitoring and maintenance personnel. Additional staffing for facility replacement [and the one-time major repair (see Appendix E, Section E.2.1.1)] would be temporary and comprise about 40 employees at a site during construction. (Construction of DOE facilities could require more workers, but the Department would have only five of these facilities reconstructed every 100 years). This temporary increase in employment would be small in proportion to the existing workforces in affected communities. Therefore, the No-Action Alternative would be unlikely to have adverse effects on socioeconomic factors such as infrastructure and regional economy.

7.2.1.7 Occupational and Public Health and Safety

7.2.1.7.1 *Nonradiation Exposures*

Maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with requirements of the Occupational Health and Safety Administration and National Institute of Occupational Safety and Health. Administrative controls and design features would minimize worker exposures to industrial nonradioactive hazardous materials during the construction and operation of the storage facilities so exposures would remain below hazardous levels.

7.2.1.7.2 *Industrial Hazards*

The industrial hazards evaluated were (1) total recordable injury and illness cases, (2) lost workday cases associated with workplace injuries and illnesses, and (3) workplace fatalities. The estimates of these traumas were based primarily on the staffing level of involved workers assigned to spent nuclear fuel and high-level radioactive waste management tasks, coupled with representative workplace loss indicators maintained by the Bureau of Labor Statistics (BLS 1998, all) or the DOE Computerized Accident/ Incident Reporting System database (DOE 1999c, all). Involved worker risk exposure estimates were based on crew sizes to determine the number of full-time equivalent work years assigned to construction and to operations, surveillance, and maintenance tasks. DOE used representative historic total recordable case, lost workday case, and fatality incident data to project the associated trauma incidence based on the number of workers and their job functions.

This analysis assumed that replacement facilities would be constructed every 100 years and that a major repair and upgrade of the initial facilities would be required once after the first 50 years. Impacts from decommissioning retired facilities were included as part of construction.

The analysis separated the short-term impacts for the first approximately 100-year period (from 2002 to 2116) from the long-term impacts for the remaining 9,900-year analysis period to enable a comparison with the short-and long-term environmental impacts associated with the Proposed Action at the Yucca Mountain Repository. This 114-year period includes the estimated time of receipt, emplacement, and monitoring of spent nuclear fuel and high-level radioactive waste at the repository between 2010 and 2110 (the assumed time when DOE would begin repository closure). It includes the period from 2002 through 2010 to enable a comparison between when a potential decision on repository development could be made through initial receipt and emplacement of spent nuclear fuel and high-level radioactive waste. The analysis included the period from 2110 through 2116 to capture the decommissioning and closure

period of the repository, again to enable comparison of continued storage and repository development. Conducting the analysis on the basis of these periods was the only way DOE could make consistent comparisons of impacts between continued storage and repository construction, operation and monitoring, and closure.

For the approximately 100-year construction and operation cycle (2002 to 2116), about 72,000 full-time equivalent work years of effort would be required to maintain and repair about 6,600 concrete storage modules and 4 below-grade storage vaults at the 72 commercial and 5 DOE sites (Orthen 1999, Table 1). Based on this level of effort, as listed in Table 7-5, about 2,300 industrial safety incidents would be likely, resulting in about 1,000 lost workday cases and 2 fatalities (an average of 1 fatality every 50 years).

In addition, for the remaining 9,900 years, Table 7-5 indicates about 290,000 estimated industrial safety incidents, of which about 130,000 would be lost workday cases and 320 would involve fatalities (an average of 1 fatality every 30 years or about one every 2,500 years at each of the 77 sites). Surveillance tasks would consume 94 percent of the total worker level of effort, construction tasks would consume nearly all of the remaining 6 percent, and operations tasks would consume less than 0.001 percent (Orthen 1999, Table 2).

Table 7-5. Estimated industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900 years of the 10,000-year analysis period under Scenario 1.[a]

Industrial safety impacts	Short-term[b] (100 years) construction and operation (2002-2116)	Long-term (9,900 years)[c] construction and operation (2116-12010)
Total recordable cases	2,300	290,000
Lost workday cases	1,000	130,000
Fatalities	2.4	320

a. Source: Orthen (1999, Tables 6 and 7).
b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and repair.
c. Period from 100 to 10,000 years.

7.2.1.7.3 *Radiation Exposures*

For Scenario 1, the analysis assumed that the facilities would undergo major repairs once during the first 100 years and would be replaced every 100 years thereafter. Very low exposures to future construction workers would occur as they built replacement facilities adjacent to the existing facilities. Transferring the dry storage canisters from old to new concrete storage modules would result in some additional exposures to workers.

During normal operations, facility workers would be exposed to low levels of external radiation while performing routine surveillance and monitoring activities, changing high-efficiency particulate air filters on ventilation systems (for high-level radioactive waste storage facilities), transferring dry storage canisters between concrete storage modules, and maintaining and repairing the facilities. In addition, individuals employed at the nearby nuclear powerplant but not directly involved with activities at the spent nuclear fuel storage facility (noninvolved workers) would be exposed to low levels of external radiation emanating from the filled concrete storage modules. Activities within the facility boundaries would be in accordance with DOE or Nuclear Regulatory Commission guidelines for nuclear facility worker protection (10 CFR Part 835 and 10 CFR Part 20). Table 7-6 lists estimated maximum annual individual doses and the total average collective dose for worker populations during the 10,000-year analysis period for commercial and DOE sites.

The Scenario 1 analysis treated the dose rates from DOE spent nuclear fuel as equivalent to commercial spent nuclear fuel on a volume basis. This simplifying assumption had minimal effect on estimated

Table 7-6. Estimated radiological impacts (dose) and consequences from construction and routine operation of commercial and DOE spent nuclear fuel and high-level radioactive waste storage facilities – Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation (2002-2116)	Long-term (9,900 years) construction[b] and operation (2116-12010)
Population[c]		
MEI[d] (millirem per year)	0.20	0.06
Dose[e] (person-rem)	810	5,200
LCFs[f]	0.41	2.6
Involved worker[g]		
MEI[h] (millirem per year)	170	50
Dose[e] (person-rem)	2,600	31,000
LCFs[f]	1.0	12
Noninvolved workers[i]		
MEI[j] (millirem per year)	13	0[k]
Dose[e] (person-rem)	36,000	0[k]
LCFs[f]	15	0[k]

a. Source: Adapted from NRC (1991, all); Orthen (1999, all).
b. Assumes construction of 6,600 concrete storage modules and three below-grade vaults at 77 sites every 100 years (Orthen 1999, Table 1).
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the duration of the analysis period [estimated using Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (NRC 1991, page 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer fatality per rem for workers and members of the public, respectively (NCRP 1993b, page 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (NRC 1991, pages 23 to 25). For this analysis, the involved worker population would be approximately 1,400 individuals (700 individuals at any one time) at 77 sites over 100 years (Orthen 1999, Table 6). This population would grow to about 160,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (NRC 1991, page 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposures until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (NRC 1991, page 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

individual and population doses because of the relatively small quantities of DOE spent nuclear fuel (less than 10 percent of the total) and essentially equal radiation exposure rates in comparison to commercial spent nuclear fuel on a volume basis. The analysis separated the calculation of dose rates from high-level radioactive waste because of the difference in source materials.

For Scenario 1, dose rates from high-level radioactive waste were estimated based on the isotopic distributions provided in Appendix A, Tables A-25, A-26, and A-27. As with commercial and DOE spent nuclear fuel, estimated dose rates to facility workers considered shielding provided by the concrete facility structures and decay over the 10,000-year analysis period. However, because of the relatively large distance from the storage facilities to the site boundary [typically more than 3 kilometers (2 miles) at the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the Savannah River Site], doses to the public were not included. Although the distance to the site boundary at the West Valley Demonstration Project is less than 3 kilometers, not including public exposures from above-grade storage facilities would result in a very small underestimation of impacts because DOE stores only about 4 percent of the high-level radioactive waste at that facility.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements. However, overall impact estimates did not include these impacts because long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

As listed in Table 7-6, the estimated dose to the hypothetical maximally exposed offsite individual during the short-term operational period between 2002 and 2116 would be about 0.20 millirem per year (NRC 1991, page 22). For the remaining 9,900 years of the analysis period (long-term impacts), the dose to the hypothetical maximally exposed individual would decrease to about 0.060 millirem per year because of radioactive decay of the source material. During about the first 100 years, the dose (accounting for radioactive decay) could result over a 70-year lifetime of exposure in an increase of 0.0000043 in the lifetime risk of contracting a fatal cancer, an increase over the lifetime natural fatal cancer incidence rate of 0.0018 percent. During the remaining 9,900 years of the analysis period, the dose could result in an increase of 0.0000013 in the lifetime risk of contracting a fatal cancer, an increase of 0.00055 percent over the lifetime natural fatal cancer incidence rate.

Based on the Nuclear Regulatory Commission computer program SECPOP (Humphreys, Rollstin, and Ridgely 1997, all), in 1990 approximately 100,000 people lived within 3 kilometers (2 miles) of some type of commercial nuclear facility (Rollins 1998, page 9). Over the 100-year analysis period, the total number of people that would be exposed would be approximately 140,000 because more than one 70-year lifetime would be spanned during the 100-year period. As listed in Table 7-6, between 2002 and 2116 these people would be likely to receive a total collective dose of 810 person-rem.

Long-term doses and latent cancer fatalities for the approximately 9,900-year period between 2116 and 12010 were based on the assumptions described above, with a few notable exceptions. Impacts to noninvolved workers were not calculated because all of the nuclear powerplants would be closed by the beginning of this period. In addition, the total exposed populations of workers and the public would increase by a factor of 100 above the 100-year exposed population because this period would span 140 lifetimes of 70 years. As noted above, for the first 100 years of operation approximately 140,000 people living within 3 kilometers (2 miles) of the storage facilities (100,000 people multiplied by 1.4 consecutive 70-year average human lifetimes [the average number of 70-year lifetimes in 100 years]) would be exposed to external radiation. Over 10,000 years the exposed population would total approximately 14 million people. Therefore, for the period between 2116 and 12010, the offsite population would receive an estimated total collective dose of 5,200 person-rem (adjusted for radioactive decay).

Population statistics indicate that in 1990 cancer caused about 24 percent of the deaths in the United States (NCHS 1993, page 5). If this percentage of deaths from cancer continued, about 24 people out of every 100 in the U.S. population would contract a fatal cancer from some cause. For approximately the first 100 years, the radiation exposure dose from the storage facilities could cause an additional 0.41 latent cancer fatality in the surrounding populations. This would be in addition to about 33,000 cancer fatalities that would be likely in the exposed population of 140,000 from all other causes, or an increase in the natural incidence rate of 0.0012 percent. For the remaining 9,900 years of the analysis, the radiation exposure dose from the storage facilities could result in an additional 2.6 latent cancer fatalities in the surrounding populations. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, or an increase of 0.000079 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be involved in constructing and loading replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour and an average exposure time of 1,500 hours per year, this construction worker

would receive about 170 millirem per year. During about the first 100 years, the dose could result (over 3 years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.090 percent over the national fatal cancer incidence rate of about 24 percent. During the remaining 9,900 years of the analysis period, the dose could result (over 3 years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060 percent, an increase of 0.030 percent over the natural fatal cancer incidence rate.

For the involved worker population of 1,400 individuals, approximately 330 would be likely to contract a fatal cancer from some cause other than occupational exposure. In this population (during the first 100 years), the collective dose of 2,600 person-rem (correcting for decay) between 2002 and 2116 could result in about 1 additional latent cancer fatality (Orthen 1999, Table 6), an increase of 0.33 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the approximately 160,000 involved workers would receive a collective dose of 24,000 person-rem (corrected for decay). This dose could result in an additional 10 latent cancer fatalities (about 1 every 1,000 years during the 9,900-year analysis period), an increase of 0.027 percent over the natural incidence rate of fatal cancers.

Noninvolved workers would be those employed at an operating nuclear powerplant but not directly involved with the day-to-day operation of the spent nuclear fuel storage facility. The analysis assumed that noninvolved workers (about 800 for each of the approximately 100 reactor units at 72 commercial sites) would be generally several hundred to several thousand feet from the storage facilities. In addition, it assumed that noninvolved workers would be at the sites until 2052 (that is, for 50 years).

The Nuclear Regulatory Commission estimated that the dose to noninvolved workers at a nuclear powerplant from a fully loaded independent spent fuel storage installation would be about 16 person-rem per year (NRC 1991, page 24) for the protected-area workforce of 1,200 individuals (NRC 1991, page 26) at the two-unit station of Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 13 millirem per year. Over a 50-year career, this exposure (accounting for radioactive decay) could result in an increase in lifetime risk of contracting a fatal cancer of 0.00018, an increase of 0.077 percent over the natural incidence rate of fatal cancers.

The analysis made the conservative assumption that there are about 80,000 powerplant workers in the United States (800 per reactor unit and about 100 units currently operating), and that these workers would receive radiation exposure from the adjacent storage facilities until powerplant decommissioning, which the analysis assumed will occur in 2052. In the total noninvolved worker population of 80,000 powerplant workers (all sites), the collective dose of 36,000 person-rem (accounting for radioactive decay) between 2002 and 2116 could result in 15 additional latent cancer fatalities. This would be about 0.079 percent more than the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

Figure 7-6 shows the calculated dose to these populations as a function of time, expressed as 70-year doses. For the noninvolved worker population, the population dose would occur during only the first 70-year interval. The public dose would decrease over time due to the inherent radioactive decay that will occur in the spent nuclear fuel and high-level radioactive waste as time elapses. Many of the radioactive constituents have half-lives substantially less than 10,000 years; therefore, it is likely that the dose to the public would decrease noticeably over time. The involved worker population dose also would decrease over time because of radioactive decay. The involved worker dose would fluctuate as new concrete storage modules were constructed and radioactive material was transferred from the old to the new modules every 100 years. During those 70-year intervals in which construction and transfer would occur,

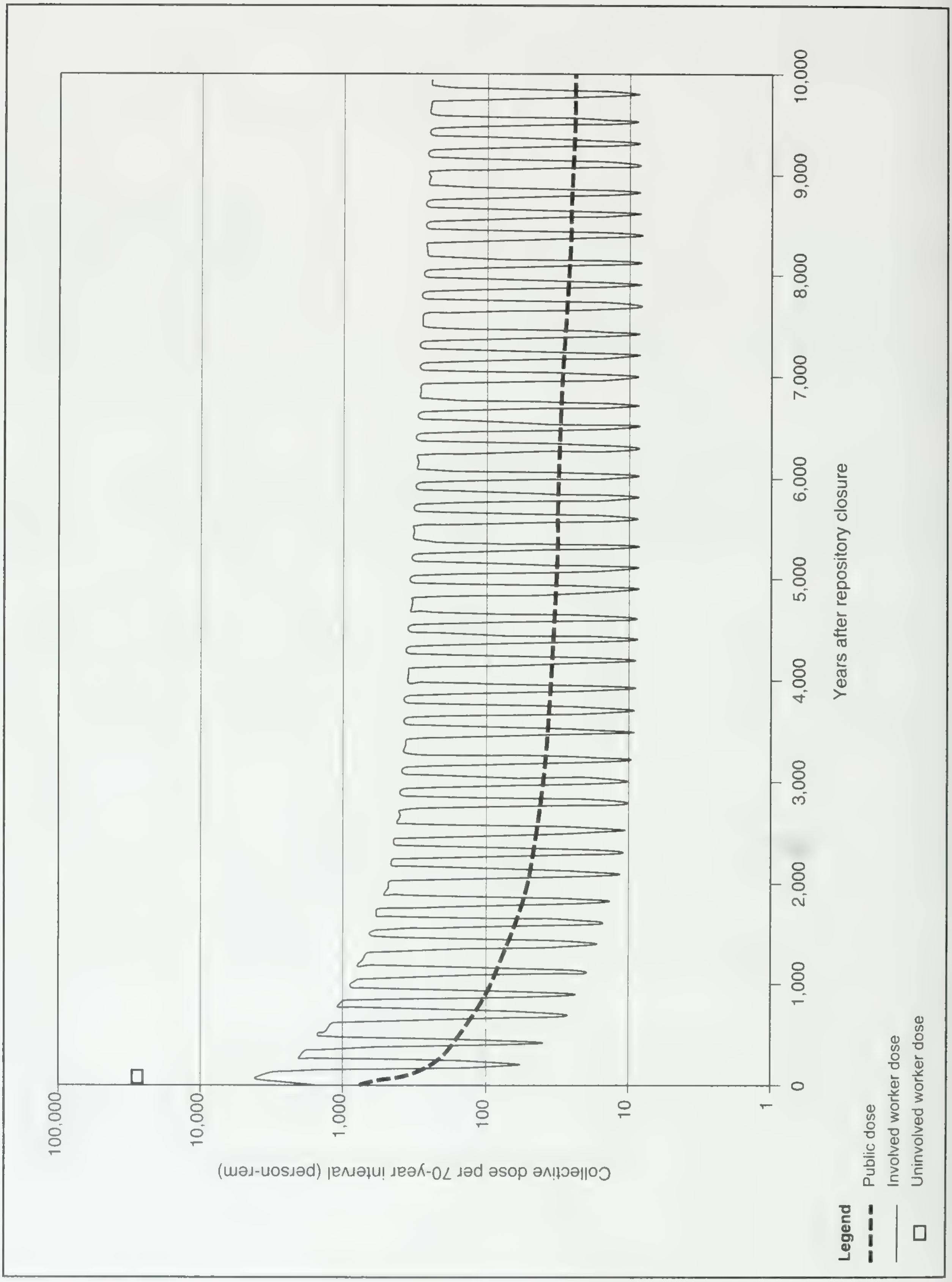


Figure 7-6. Collective dose for 70-year intervals for No-Action Scenario 1.

the dose would be higher; the dose would be lower during those 70-year intervals when these activities did not occur.

Because no liquid or airborne effluents would emanate from the storage facilities, direct and air-scattered radiation would comprise the total source of radiation exposure to the public. For populations more than 3 kilometers (2 miles) from the facilities (as is the case for most DOE facilities), direct and air-scattered external radiation exposure would be small (NRC 1991, page 22).

7.2.1.8 Accidents

For Scenario 1, activities at each facility would include surveillance, inspection, maintenance, and equipment replacement, when required. The facilities and the associated systems, which the Nuclear Regulatory Commission would license, would have certain required features. License requirements would include isolation of the stored material from the environment and its protection from severe accident conditions. The Nuclear Regulatory Commission requires an extensive safety analysis that considers the impacts of plausible accident-initiating events such as earthquake, fire, high wind, and tornado. In addition, the license would specify that facility design requirements include features to provide protection from the impacts of severe natural events. This analysis assumed indefinite maintenance of these features for the storage facilities.

DOE performed an analysis to identify the kinds of events that could lead to releases of radioactive material to the environment prior to degradation of concrete storage modules and found none. The two events determined to be the most challenging to the integrity of the concrete storage modules would be the crash of an aircraft into the storage facility and a severe seismic event.

- Davis, Strenge, and Mishima (1998, all) concluded that the postulated aircraft crash would be potentially more severe than a postulated seismic event because storage facility damage from an aircraft crash probably would be accompanied by a fire. The analysis showed that hurtling aircraft components produced by such an event would not penetrate the storage facility and that a subsequent fire would not result in a facility failure. This conclusion is consistent with representative analyses performed in support of Nuclear Regulatory Commission license applications for above-grade dry storage (PGE 1996, all; CP&L 1989, all).

- For the seismic event, major damage would be unlikely because storage facilities would be designed to withstand severe earthquakes. Even if such an event caused damage, immediate release of radioactive particulates would be unlikely because analyses have identified no mechanism that would cause fuel pellet damage sufficient to create respirable airborne particles (PGE 1996, all; CP&L 1989, all). Therefore, the source term would be limited to gaseous fission products, carbon-14, and a very small amount of preexisting fuel-pellet dust. Subsequent repairs to damaged facilities or concrete storage modules would preclude the long-term release of radionuclides.

Criticality events are not plausible for Scenario 1 because water, which is required for criticality, could not enter the dry storage canister. The water would have to penetrate several independent barriers, all of which would be maintained and replaced as necessary under Scenario 1. Therefore, DOE determined that potential accident consequences would be bounded by a severe seismic event (see Appendix K, Section K.2.5). DOE analyzed this event and concluded that such an accident scenario would not result in radiological impacts to members of the public in the immediate vicinity of the storage facility. In addition, there would be limited quantities of nonradioactive hazardous or toxic substances stored at the facilities. Therefore, nonradiological accident impacts would be limited to those from industrial hazards and traffic, as discussed in Sections 7.2.1.7.2 and 7.2.1.14, respectively.

7.2.1.9 Noise

During routine operations, noise levels would not affect workers, the public near the facility, or the environment. Most of the storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Because the storage facilities would be away from population centers or homes, the noise of blowers, if used, would not affect the nearby public. The noise would not be loud enough to produce adverse impacts on the facility workers' hearing.

The analysis assumed for Scenario 1 that the storage facilities would require complete replacement every 100 years. During construction, noise levels due to construction traffic and activities would exceed ambient noise levels. To protect personnel, Occupational Safety and Health Administration standards would be followed (29 CFR 1910.95). The noise could cause wildlife to leave the immediate vicinity of the construction activities, but would not be loud enough to affect individual animals permanently. Adverse impacts to wildlife would be temporary.

7.2.1.10 Aesthetics

Impacts from the storage facilities to aesthetic or scenic resources would be low. There would be two adjacent locations at each site on land that would already be disturbed. Every 100 years, a new facility would be constructed on the idle site, and the storage containers transferred. The old facility would be demolished and the site would remain idle for the next 100 years. Adverse impacts could occur during construction and demolition activities, but these impacts would be short-term and temporary.

7.2.1.11 Utilities, Energy, and Materials

As mentioned above, spent nuclear fuel and high-level radioactive waste storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Electricity would be required for these cooling systems and to light the storage facilities, but DOE anticipates that the amount of electricity would be small in comparison to the amount available. Fuel and materials would be needed to maintain and repair the facilities and to construct and demolish facilities every 100 years, but DOE expects impacts to these resources to represent a small fraction of the resources available to each of the 77 sites. Therefore, the No-Action Alternative would not produce adverse impacts on these resources during operation and construction activities.

7.2.1.12 Waste Management

Construction of new facilities and demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during construction periods. The greatest amount of waste would be generated by the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 770,000 cubic meters (1 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister were to fail while in storage (Orthen 1999, Table 7). The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to any one disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

7.2.1.13 Environmental Justice

Potential impacts of continued storage with institutional control would be minimal for all populations living near the storage facilities. Because adverse impacts would be unlikely for any population, effects on minority or low-income populations would be unlikely to be disproportionately high and adverse.

Storage facilities would require small areas and would be on lands already owned by commercial utilities or DOE. Therefore, continued storage at these sites would be unlikely to introduce environmental justice issues. If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to determine if environmental justice issues could result. The Nuclear Regulatory Commission has established this approach (NRC 1996, page 9-16).

7.2.1.14 Traffic and Transportation

DOE analyzed short-term impacts (traffic fatalities) that could result from commuting to and from storage facilities for a single 100-year cycle. The amount of travel was determined from estimates of personnel needed to construct the storage facilities, load and reload the canisters into the storage modules, and conduct routine surveillance and repairs (Orthen 1999, all). Because the workforce at each storage facility would be small, opportunities for carpooling would be limited. Therefore, the analysis assumed each worker would commute individually.

An estimated 700 workers (see Section 7.2.1.7.3) would commute to and from work approximately 18 million times during the first 100 years. The analysis assumed an average one-way commute of 19 kilometers (12 miles) based on personal travel reported in the Nationwide Personal Transportation Survey by the Oak Ridge National Laboratory (ORNL 1999, page 9). The analysis also used national data to estimate fatalities [in 1994, 1 fatality per 100 million kilometers (about 62 million miles) traveled by automobile (BTS 1999b, page 4)] over a single 100-year period. Based on the expected workforce, estimated number of trips, estimated average distance, and fatality data, approximately 7 traffic fatalities would occur in the workforce at the 77 sites in 100 years (or an average of less than 1 fatality every 10 years) (Orthen 1999, Table 6).

In addition, the analysis estimated the long-term traffic fatalities for the remaining 9,900-year analysis period. Using the estimated number of full-time equivalent work years of 7.4 million, about 730 traffic fatalities would be likely during the 9,900-year analysis period at the 77 sites (or, on average, less than 1 fatality every 10 years).

The analysis also estimated traffic fatalities and latent cancer fatalities from trucks transporting construction materials to and demolition debris from the 77 sites assuming an 80-kilometer (50-mile) roundtrip distance. For the 9,900-year period, during the construction of replacement facilities, construction vehicles would travel about 1.2 billion kilometers (750 million miles), resulting in approximately 26 prompt traffic fatalities, or less than 1 fatality every 300 years (BTS 1999b, page 4) and 0.1 latent cancer fatality from vehicle exhaust emissions (Orthen 1999, Table 7).

7.2.1.15 Sabotage

Storage of spent nuclear fuel and high-level radioactive waste over 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. In addition, intruders could attempt to remove fissile material, which could result in releases of radioactive material to the environment. Under Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the

10,000-year analysis period at the 77 sites. Therefore, the risk of sabotage would continue to be low. However, as discussed in the Record of Decision (*62 FR* 3014, January 21, 1997) for the *Storage and Disposition of Weapons-Usable Fissile Materials Final Environmental Impact Statement* (DOE 1997n, all), disposition and storage does not make it impossible to recover plutonium for use in weapons. Therefore, the difficulty of maintaining absolute control over 77 sites for 10,000 years would suggest that the cumulative risk of intruder attempts could increase.

7.2.2 NO-ACTION SCENARIO 2

DOE and commercial utilities intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years to provide a basis for evaluating an upper limit of potential adverse human health impacts to the public from the continued storage of spent nuclear fuel and high-level radioactive waste. After about 100 years, Scenario 2 assumes that there would be no effective institutional control and that the storage facilities would be abandoned. Therefore, there would be no health risks for workers during that period. For the long-term impacts after about 100 years and for as long as 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that radioactive materials would be released to the environment, contaminating the local atmosphere, soil, surface water, and groundwater. Appendix K provides details of facility degradation, radioactive material environmental transport, and human radiological exposure and dose models.

Because Scenario 2 assumes effective institutional control during the first 100 years of the 10,000-year analysis period, the short-term impacts of that first 100 years would be the same as the impacts described for Scenario 1 (see Section 7.2.1). Therefore, this discussion focuses on long-term impacts (after the first approximately 100 years). However, after about 100 years under Scenario 2, when there would no longer be effective institutional control, construction and operation activities would not occur at the storage sites; therefore, socioeconomic and cultural resources would be unlikely to receive adverse impacts. In addition, noise would not emanate from the facilities; utilities, energy, or materials would not be expended; waste would not be generated; and workers would not commute to the sites. Thus, after approximately the first 100 years, No-Action Alternative Scenario 2 would not adversely affect cultural resources; scenic resources; noise; utilities, energy and materials; waste management; or traffic and transportation. Aesthetic resources would not change until the facilities began to degrade, at which time the aesthetic value of the sites would change.

7.2.2.1 Land Use and Ownership

Without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate. Eventually radioactive materials would contaminate the land surrounding the storage facilities, possibly rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The amount of land contaminated would depend on several factors including the climate of the region, the amount of spent nuclear fuel and high-level radioactive waste at the site, and the rate of deterioration. Although the size of the affected area would be impossible to predict accurately for each site, DOE believes it would involve tens to hundreds of acres at each of the 77 sites.

By assuming that there would be no effective institutional control, this scenario also assumes that there would not be an orderly conversion of land use and ownership to other uses or ownership and that all knowledge of the purpose and content of the facilities would be lost. This would increase the likelihood that members of the public would move onto storage facility lands because they would not be aware of the potential radioactive material contamination.

7.2.2.2 Air Quality

As discussed in Appendix K, Section K.2.3, the degraded facilities would provide sufficient protection of the spent nuclear fuel and high-level radioactive waste materials to preclude the release of particulate radioactive materials in sufficient quantities to affect air quality adversely. Small releases of gaseous carbon-14 would be likely in the form of carbon dioxide gas but would not adversely affect ambient air quality.

7.2.2.3 Hydrology

7.2.2.3.1 *Surface Water*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter surface waters from stormwater runoff from the failed facilities and storage containers and exposed radioactive materials. The introduction of contaminants would continue over a long period until the depletion of the source materials. During this release period, contaminant releases to surface waters could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using this water for drinking.

7.2.2.3.2 *Groundwater*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter the groundwater. Once contaminated, aquifers beneath the degraded storage facilities would remain contaminated for the period required for the depletion of the spent nuclear fuel and high-level radioactive waste materials and the migration of the contaminants from the groundwater system. Contaminant concentrations in the groundwater could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using groundwater for drinking, bathing, and irrigation.

7.2.2.4 Biological Resources and Soils

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, the potential for individual animals to be exposed to radiation at the storage sites would increase. In addition, animals could drink contaminated surface water. Direct radiation from the exposed spent nuclear fuel and high-level radioactive waste storage canisters and concentrations of contaminants in surface waters could produce adverse impacts to animals. While the contaminant exposure could have negative effects, including death, on individual animals, adverse effects to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Soils at the storage facilities could be contaminated by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material. Soils downslope of the facilities could be contaminated by surface-water runoff. Crops grown on these soils would take up some of the contamination, thus making the contaminated soils a pathway for human exposure. Section 7.2.2.5.3 discusses impacts to members of the public from ingesting food grown in or livestock fed from contaminated soils.

7.2.2.5 Occupational and Public Health and Safety

7.2.2.5.1 *Nonradiation Exposures*

Analyses performed for the repository (see Chapter 5, Section 5.6) indicate that uranium concentrations from degraded spent nuclear fuel and high-level radioactive waste in the groundwater would be extremely low. Therefore, because of the relatively greater abundance of water and the greater precipitation at the storage locations than at the repository, uranium concentrations in the groundwater and surface water at the storage sites would be much lower than those estimated for the repository. The only other toxic material, chromium, would be present in the packaging at the storage sites in extremely low concentrations [most of the chromium analyzed at the repository comes from corrosion-resistant alloys (Alloy-22) that would not be present in continued storage location packaging materials]. Therefore, concentrations of chemically toxic materials would be extremely low and probably would not result in adverse impacts.

7.2.2.5.2 *Industrial Hazards*

For about the first 100 years, industrial hazards would be the same as for the first 100 years under Scenario 1 (see Section 7.2.1.7.2). After about 100 years, Scenario 2 assumes there would be no effective institutional control and that the storage facilities would be abandoned and, therefore, there would be no industrial safety impacts.

7.2.2.5.3 *Radiation Exposures*

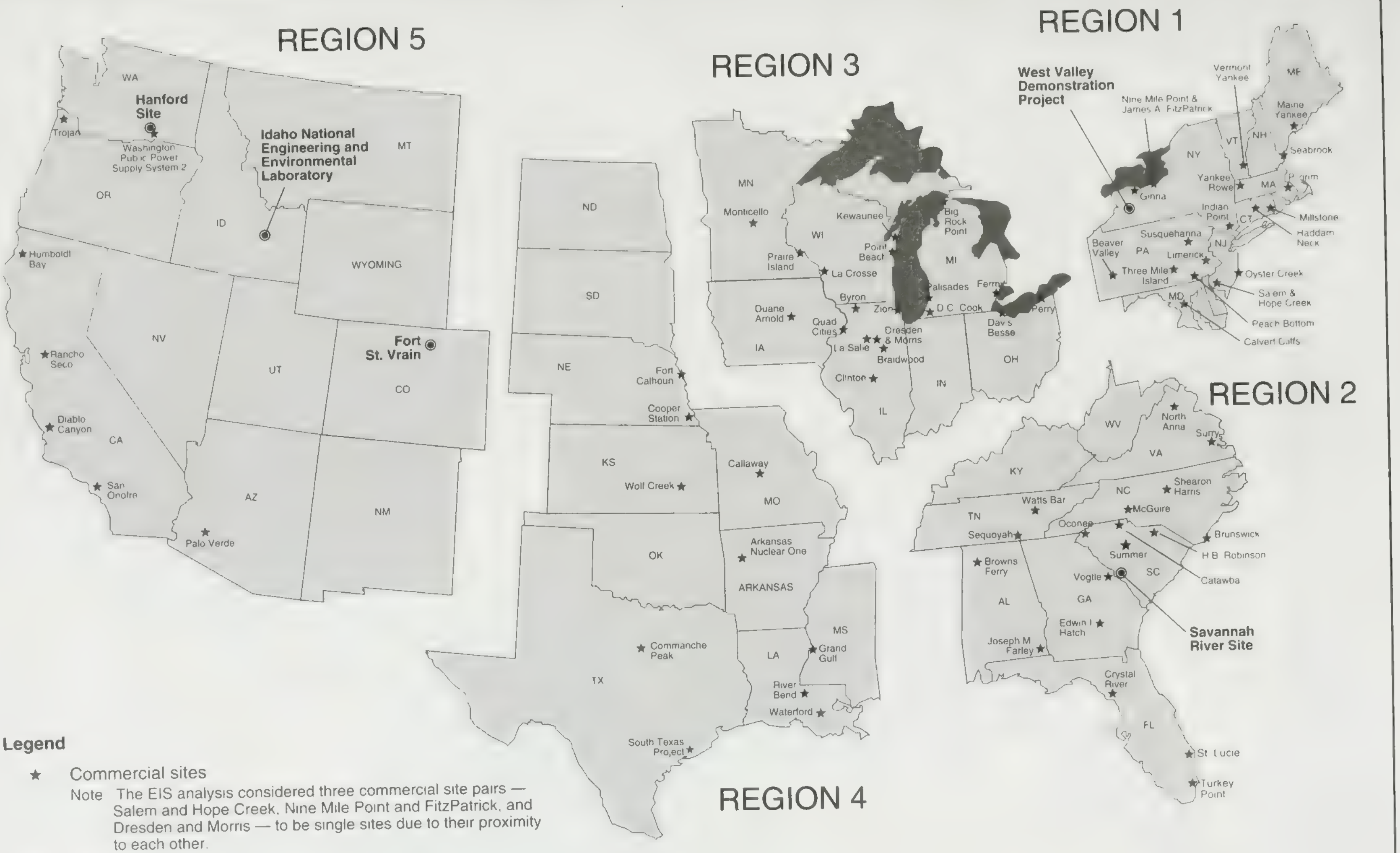
To simplify the analysis, DOE divided the United States into five regions (Figure 7-7). Regional radiological impacts were estimated by assuming all spent nuclear fuel and high-level radioactive waste in a particular region was stored at a single hypothetical site in that region. Appendix K, Section K.2.1.6, provides details of the methods and assumptions used in the regional analysis.

Radiological impacts to occupational workers and the offsite public from initial construction, routine maintenance and operations, and refurbishment after the first 50 years would be the same as those for the same period under Scenario 1 (see Section 7.2.1.7.3 and Table 7-6).

For Scenario 2 DOE assumed that after approximately the first 100 years there would be no institutional control and that deterioration of the facilities would occur over time. Based on regional climate and degradation models (see Appendix K), the spent nuclear fuel and high-level radioactive waste storage facilities and dry storage containers would corrode and fail over time, exposing radioactive material to the environment (wind and rain). Once exposed to the environment, the spent nuclear fuel and high-level radioactive waste storage packages and facilities would begin releasing small quantities of radioactive material to the atmosphere (gaseous carbon-14), soil, surface water, and groundwater, resulting in exposures to the public. These released materials could produce chronic exposures to the public, which could result in adverse health impacts. Figure 7-8 shows the conceptual timeline for activities and degradation processes at the storage facilities for Scenario 2.

Appendix K describes the methods used to estimate impacts to human health from long-term environmental releases and human intrusion. The radiological impacts on human health include internal exposure from intake of radioactive materials in surface water and groundwater.

Table 7-7 lists the estimated radiological drinking water impacts during the 9,900 years under Scenario 2 with the assumption of no effective institutional control. The impacts listed in Table 7-7 are from drinking water only and would result from consuming water from the major waterways contaminated with



Legend

★ Commercial sites

Note The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste and spent nuclear fuel at West Valley. The State of New Yorkowns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste off the West Valley site. DOE owns and is responsible for the spent nuclear fuel at the site

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Figure 7-7. Commercial and DOE sites in each No-Action Alternative analysis region.

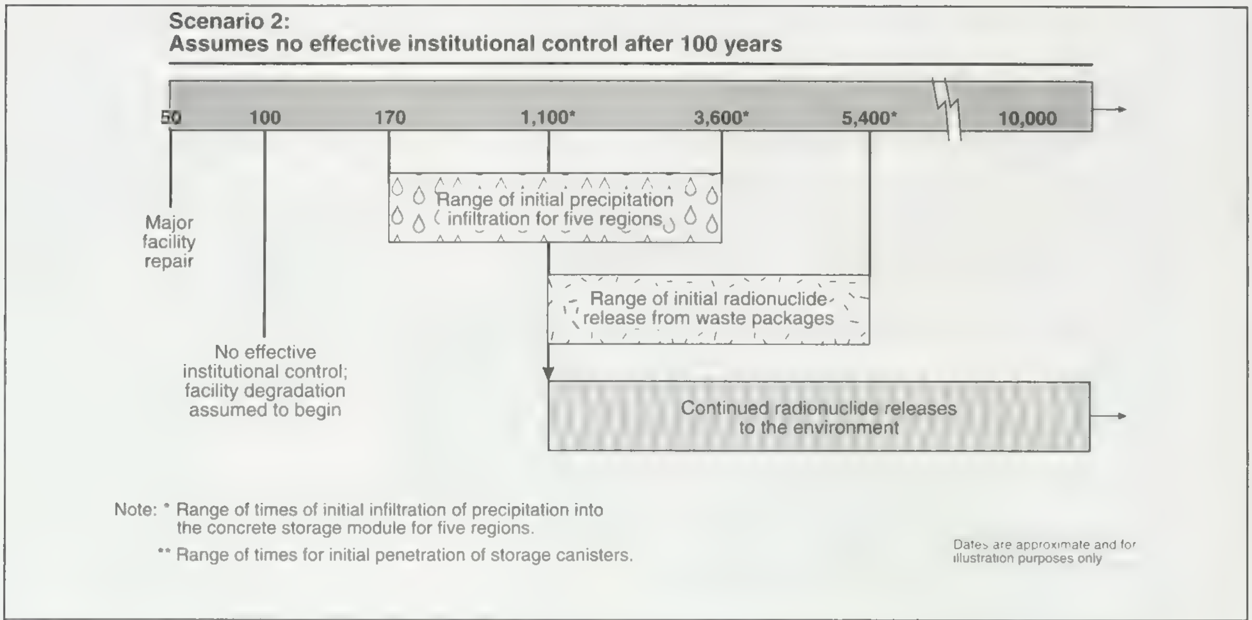


Figure 7-8. Conceptual timeline for activities and degradation processes for No-Action Scenario 2.

Table 7-7. Estimated long-term collective drinking water radiological impacts to the public from long-term storage of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites – Scenario 2.

9,900-year population dose[a] (person-rem)	9,900-year LCFs[b]	Years to peak impact[c]
6,600,000	3,300	3,400

a. Estimated total population (collective) dose from drinking water pathway (Toblin 1998, page 4).

b. LCFs = latent cancer fatalities; estimated for the exposed population group based on an assumed risk of 0.0005 latent cancer fatality per person-rem of collective dose (NCRP 1993b, page 112).

c. Years after period of institutional control when the maximum doses would occur.

radioactive materials by groundwater discharge and surface-water runoff from degraded spent nuclear fuel and high-level radioactive waste storage facilities. DOE evaluated other potential impacts to populations (for example, exposure to people living on the contaminated floodplains) and to individuals (for example, consumption of contaminated food) and determined that certain individuals could receive doses as much as three times higher than for drinking water alone but that doses to populations from contaminated floodplains would represent less than 10 percent of the impacts listed in Table 7-7. DOE did not include these impacts in Table 7-7 because the dose to an individual would depend largely on highly variable subsistence habits and because DOE did not want to overestimate the impacts from Scenario 2.

Figure 7-9 shows the locations of the commercial and DOE sites in the United States and the more than 20 major waterways potentially affected. At present, municipal water systems that serve 31 million people have intakes along the potentially affected portions of these waterways. The analysis assumed these populations would remain constant over the entire analysis period (9,900 years). Over the 9,900-year analysis period, about 140 70-year lifetime periods would be affected. Because the analysis estimated that releases would not occur during the first 1,000 years for most regions, the estimated potentially exposed population would be about 3.9 billion.

Table 7-7 indicates that over 9,900 years, a collective drinking water dose of 6.6 million person-rem could result in an additional 3,300 latent cancer fatalities in the total potentially exposed population of 3.9 billion. This latent cancer fatality rate would affect an average of about 24 people per 70-year

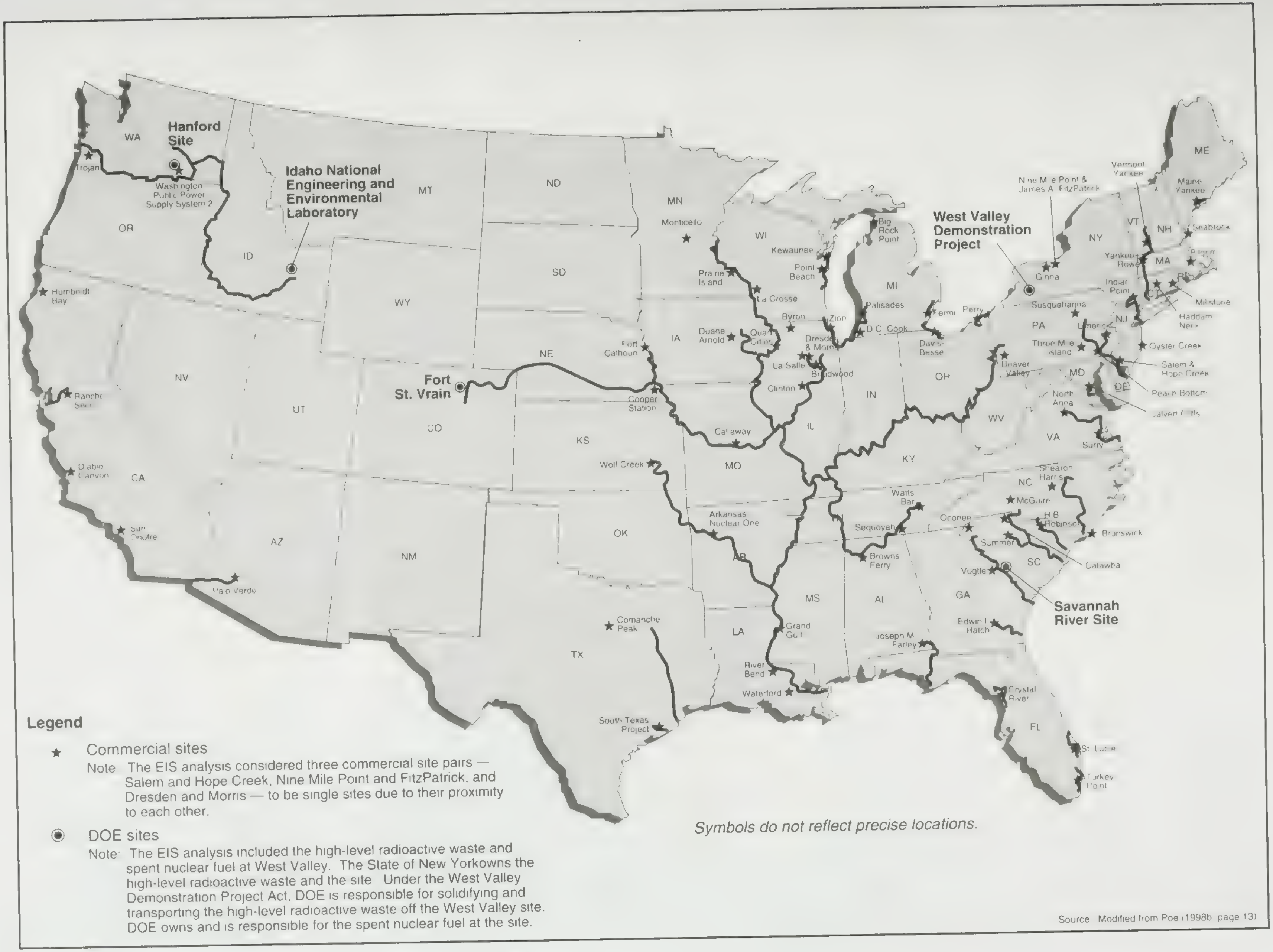


Figure 7-9. Major waterways near commercial and DOE sites.

lifetime, or about 1 latent cancer fatality at each of the 77 sites every 200 years. These radiation-induced latent cancer fatalities would be in addition to about 900 million fatal cancers (using the lifetime fatal cancer risk of 24 percent [NCHS 1993, page 5]) that would be likely from all other causes in the exposed population, an incremental increase over the natural incidence of fatal cancer of about 0.0004 percent.

Figure 7-10 shows the estimated latent cancer fatalities for approximately 140 70-year periods during the 9,900-year period of analysis. The five peaks shown in Figure 7-10 generally result from contributions of each of the five regions (see Appendix K, Figure K-8). The major peak, which would occur about 3,400 years after effective institutional control ended (in 2100), would be due to radionuclide releases at the sites that drain to the Mississippi River and the relatively large populations along the Mississippi and its tributaries.

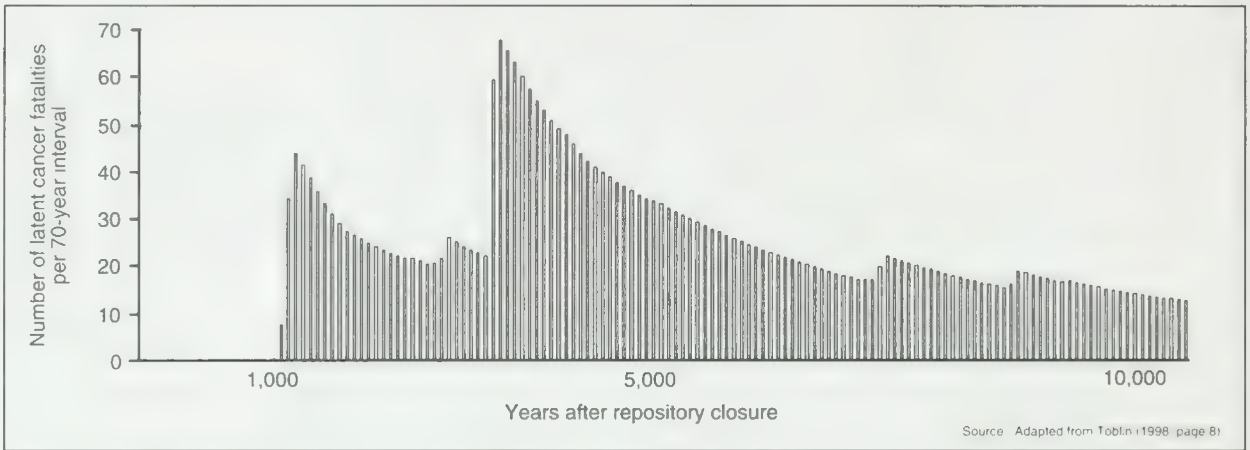


Figure 7-10. Potential latent cancer fatalities throughout the United States from No-Action Scenario 2.

In addition to the 3,300 potential cancer fatalities under Scenario 2, more than 20 major waterways of the United States that currently supply domestic water to about 31 million people (for example, the Great Lakes; the Mississippi, Ohio, and Columbia Rivers; and many smaller rivers along the Eastern Seaboard) could be contaminated with radioactive material. Under this scenario, the shorelines could be contaminated with long-lived radioactive materials (for example, plutonium, uranium, and americium), resulting in exposures to individuals who came in contact with the sediments and, potentially, an increase in latent cancer fatalities. Because individuals would not be in constant contact with the sediments, these impacts represent a small fraction of the impacts estimated for the drinking water pathways listed in Table 7-7.

For purposes of comparison with impacts associated with the Proposed Action, DOE evaluated potential radiological impacts for a maximally exposed individual by constructing hypothetical exposure scenarios for individuals living near the degraded facilities. The exposure scenarios maximized external and internal exposure over each 70-year lifetime period in the 9,900-year period of analysis. The following paragraphs describe the results of these evaluations.

For Scenario 2, localized impacts to individuals from degraded facilities at the 77 sites could be severe. DOE estimated that within a few hundred years at the several sites where early concrete failure was predicted, hypothetical individuals living close to the storage facilities would receive lethal doses of external radiation [800 millirem per hour at a distance of 10 meters (33 feet)] from the exposed dry storage containers (see Appendix K, Section K.2.4.3.2).

To evaluate impacts from ingestion of radioactive materials, the analysis assumed that individuals would live near the degraded storage facilities and would consume contaminated groundwater and food from gardens irrigated with groundwater withdrawn from the contaminated aquifer directly below their locations. DOE estimated that within 6,000 years from now a hypothetical individual living within several hundred meters of a degraded facility could receive an internal committed effective dose equivalent to several thousand rem per year from ingestion of plutonium-239 and -240 (see Appendix F for further information on committed dose equivalent). Using the National Council on Radiation Protection and Measurements risk factors (NCRP 1993b, page 112), ingestion of plutonium at this rate could increase the individual's lifetime risk of contracting a fatal cancer after only a few years of exposure.

In addition, DOE estimated impacts for a hypothetical individual living 5 kilometers (3 miles) from the degraded facility on the downgradient of the contaminated aquifer. Although this individual would be too distant from the facility to receive any appreciable external radiation dose, the internal dose from the consumption of contaminated groundwater and contaminated crops could still be as high as 30 rem per year from ingestion of plutonium-239 and -240. Ingestion of plutonium at this rate could increase the individual's risk of contracting a fatal cancer after several decades of exposure. Appendix K provides details on the methods DOE used to evaluate localized impacts.

7.2.2.6 Atmospheric Radiological Consequences

As discussed in Appendix K, Section K.2.3.3, the analysis assumed that the configuration of the degraded storage facilities would cause debris to cover the radioactive material, which would remain inside the dry storage canisters. While the dry storage canisters could fail sufficiently to permit water to enter, they would probably retain their structural characteristics, thereby minimizing the dispersion of particulate radioactive material to the atmosphere (Mishima 1998, all). However, the radionuclides carbon-14 and iodine-129 would have a relatively large inventory and a potential for gas transport. Although iodine-129 can exist in a gas phase, DOE expects it would dissolve in the precipitation and migrate in surface water and groundwater.

7.2.2.7 Accidents

For Scenario 2, the analysis examined the impacts of accident scenarios that could occur during the above-ground storage of spent nuclear fuel and high-level radioactive waste and concluded that the most severe accident scenarios would be an airplane crash into a concrete storage module and a severe seismic event.

In Scenario 2, the concrete storage modules would deteriorate with time. DOE concluded that an airplane crash into a degraded concrete storage module would dominate the consequences from external initiating events (see Appendix K, Section K.3.2.1). The analysis evaluated the potential for criticality accidents and concluded that an event severe enough to produce large consequences would be extremely unlikely, and that the consequences would be bounded by the airplane crash consequences. Table 7-8 lists the consequences of an airplane crash on a degraded concrete storage module.

Table 7-8. Estimated consequences of an aircraft crash on a degraded spent nuclear fuel concrete storage module.[a]

Impact	High population site[b]	Low population site[c]
Collective population dose (person-rem)	26,000	6,100
Latent cancer fatalities	13	3

a. Source: Davis, Strenge, and Mishima (1998, page 11).
b. Within 80 kilometers (50 miles) of site, an average of 330 persons per square mile.
c. Within 80 kilometers of site, an average of 77 persons per square mile.

7.2.2.8 Environmental Justice

Deteriorating facilities, storage containers and packaging, and spent nuclear fuel and high-level radioactive waste could produce adverse effects to the nearby public. Any nearby minority or low-income communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of any affected minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns for low-income and minority populations could vary from those of persons not in these groups, any affected low-income and minority populations could be exposed to greater than average doses. The result of differing potentials for exposure could be disproportionately high and adverse impacts to minority or low-income populations.

If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to identify if environmental justice issues could result. The Nuclear Regulatory Commission established this approach (NRC 1996, page 9-16). With the assumption of no effective institutional control after about 100 years, potential environmental justice issues identified under Scenario 2 probably would be more severe than those identified under Scenario 1 (see Section 7.2.1.13).

7.2.2.9 Sabotage

For Scenario 2, the storage of spent nuclear fuel and high-level radioactive waste over 10,000 years without institutional controls would entail a greater risk of intruder access at the 77 sites than current conditions. Potential sabotage could result in a release of radionuclides to the environment around the facility. In addition, intruders could attempt to remove fissile material, which could result in releases of radioactive material at remote sites. The analysis assumed that safeguards and security measures would not be maintained at the 77 sites after approximately the first 100 years. For the remaining 9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. The stored spent nuclear fuel and high-level radioactive waste would not be in a weapons-usable form. The condition of the spent nuclear fuel and high-level radioactive waste would require the application of specialized equipment and technologies to reprocess it into a weapons-usable form. However, as discussed in the Record of Decision (*62 FR* 3014, January 21, 1997) for the *Storage and Disposition of Weapons-Usable Fissile Materials Final Environmental Impact Statement* (DOE 1997n, all), disposition and storage does not make it impossible to recover plutonium for use in weapons. In addition, the material would contaminate areas with radioactivity if released from its storage containers. Therefore, the risks of sabotage would increase substantially under this scenario in comparison to Scenario 1.

7.3 Cumulative Impacts for the No-Action Alternative

DOE evaluated the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the Proposed Action analysis. To provide a direct comparison of impacts with the Proposed Action, the No-Action analysis in Sections 7.1 and 7.2 evaluated the impacts of the continued storage of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites across the United States. DOE chose the volume of 70,000 MTHM for analysis because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement of more than 70,000 MTHM in a first repository until a second repository is in operation. This section describes the results of the analysis of the cumulative impacts of the continued storage at the 77 existing sites of all spent nuclear fuel and high-level radioactive waste (called Inventory Module 1) (Table 7-9). Chapter 8 discusses the cumulative impacts of disposing of radioactive waste at the Yucca Mountain repository in excess of the Proposed Action repository.

Table 7-9. Inventories for Proposed Action and Module 1.[a]

Material	Proposed Action	Module 1
DOE spent nuclear fuel	2,333 MTHM	2,500 MTHM
Commercial spent nuclear fuel	63,000 MTHM	105,000 MTHM
High-level radioactive waste	8,315 canisters	22,280 canisters
Surplus plutonium[b]	50 MTHM	50 MTHM

a. Source: Appendix A, Section A.1.1.4.1.

b. The surplus plutonium (fissile material) would be in the form of mixed-oxide fuel (assumed to be 32 MTHM) or encapsulated into high-level radioactive waste canisters (assumed to be 18 MTHM) and, for purposes of storage analysis, is included in the commercial spent nuclear fuel and high-level radioactive waste canister inventories, respectively.

The Council on Environmental Quality regulations that implement the procedural provisions of the National Environmental Policy Act of 1969, as amended (42 USC 4321 *et seq.*), define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). Cumulative impact assessment is based on both the geographic (spatial) and time (temporal) considerations of past, present, and reasonably foreseeable actions. Geographic boundaries can vary by discipline depending on the time an effect remains in the environment, the extent to which the effect can migrate, and the magnitude of the potential impact. The proximity of other actions to the spent nuclear fuel storage sites is not the only decisive factor for determining the inclusion of an action in the assessment of cumulative impacts. Another, and for this analysis more important, factor is if the other actions would have some influence on the resources in the same time and space affected by continued storage (CEQ 1997, page 17).

The cumulative impacts of past actions have either passed through the environment or are part of existing baseline conditions. For example, the construction impacts of spent nuclear fuel storage facilities will have passed through the environment before the potential impacts associated with continued storage and refurbishment would first be seen in 2002.

DOE based its estimates of the potential impacts from continued storage of commercial spent nuclear fuel on a representative site. The results of the analysis described in the previous section are consistent with the Nuclear Regulatory Commission's findings in its *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (NRC 1996, pages 6-85 and 6-86). The NRC stated:

> *The Commission's regulatory requirements and the experience with on-site storage of spent fuel in fuel pools and dry storage has been reviewed. Within the context of a license renewal review and determination, the Commission finds that there is ample basis to conclude that continued storage of existing spent fuel and storage of spent fuel generated during the license renewal period can be accomplished safely and without significant environmental impacts. Radiological impacts will be well within regulatory limits; thus radiological impacts of on-site storage meet the standard for a conclusion of small impact. The nonradiological environmental impacts have been shown to be not significant; thus they are classified as small. The overall conclusion for on-site storage of spent fuel during the term of a renewed license is that the environmental impacts will be small for each plant. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of spent fuel.*

Although this finding is applicable only to the continued storage of existing spent nuclear fuel and spent nuclear fuel generated during the 20-year license renewal period for the nuclear powerplant, DOE has concluded that potential environmental and radiological impacts for the storage facility would remain small for much longer periods. Environmental impacts would remain small because no additional fuel would be generated beyond the operation of the nuclear powerplant (plants are assumed to be closed after

the first 20-year license renewal period), and radiological impacts would remain within regulatory limits specified in the storage facility license (10 CFR Part 172).

In general, the analysis of cumulative effects can exclude future actions if:

- The action is outside the geographic boundaries or timeframe established for the cumulative effects analysis.
- The action will not affect resources that are the subject of the cumulative effects analysis.
- Including the action would be arbitrary (CEQ 1997, page 19).

Because the estimated impacts would be small, DOE has not attempted to speculate on other arbitrary generic actions that could influence the cumulative impacts generated at a given site. However, the total incremental impact nationally of selected parameters is presented in the preceding section. In addition, the potential impacts at each site do not overlap because the storage sites are located throughout the United States. Therefore, cumulative impacts among the sites on resources would be unlikely.

For the 5 DOE sites, there is a long legacy of EISs and annual monitoring reports. The incremental impacts associated with continued storage of spent nuclear fuel can be added to the results reported in these documents to obtain an estimate of total impacts. For the 72 diverse commercial sites, information on other present and reasonably foreseeable actions varies in terms of data availability and quality. As a consequence, a comparison of cumulative assessments would be problematic, even if the impacts were not as small as the analyses indicate.

The cumulative analysis in this section includes the total projected inventory of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste (referred to as Module 1) that would come to the repository. Table 7-9 lists the inventories for the Proposed Action analysis and the Module 1 cumulative analysis.

For consistency with the cumulative impact analysis in Chapter 8, the No-Action analysis considered the same spectrum of environmental impacts as the Proposed Action. Quantitative estimates of the cumulative impacts in this section are limited to the disciplines for which DOE made quantitative assessments for the Proposed Action, as discussed in Section 7.2. These disciplines include occupational and public health and safety, waste management, and traffic and transportation. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely, the Department decided to focus the No-Action cumulative analysis on the short- and long-term health and safety of workers and members of the public. The qualitative discussions of other disciplines are included for completeness.

DOE recognizes that approximately 2,054 cubic meters (10,900 cubic feet) of commercial low-level radioactive waste will exceed Nuclear Regulatory Commission Class C limits (listed in 10 CFR 61.55, Tables 1 and 2 for long and short half-life radionuclides, respectively). This type of waste, called *Greater-Than-Class-C low-level waste*, is generally not suitable for near-surface disposal (see Appendix A, Section A.2.5, for a detailed description). Similarly, DOE low-level radioactive waste that exceeds the Nuclear Regulatory Commission Class C limits (referred to as *Special-Performance-Assessment-Required waste*) will amount to about 4,017 cubic meters (142,000 cubic feet) (see Appendix A, Section A.2.6, for a detailed description). Together these waste types, added to the Module 1 inventory, comprise the Module 2 inventory.

The NWPA does not specifically consider Greater-Than-Class-C or Special-Performance-Assessment-Required wastes. Therefore, DOE has not included either waste type in the Proposed Action inventory for the consideration of potential impacts that could occur from the disposal of spent nuclear fuel and high-level radioactive wastes in a geologic repository at Yucca Mountain. The disposal of these wastes at Yucca Mountain, however, is part of the cumulative impact analysis (see Chapter 8) because the impacts of that disposal are reasonably foreseeable as the results of future actions.

Further, DOE has not included Module 2 in its consideration of potential impacts under the No-Action Alternative. DOE does not have enough information about Module 2 wastes at present to be able to perform a meaningful analysis with respect to the No-Action Alternative. As discussed in Appendix A, Section A.2.5, Greater-Than-Class-C waste could include, for example, certain commercial nuclear powerplant operating and decommissioning wastes and sealed radioisotope sources. DOE Special-Performance-Assessment-Required waste could include certain production reactor operating wastes, production and research reactor decommissioning wastes, sealed radioisotope sources, and isotope production-related wastes (see Appendix A, Section A.2.6). As just one example of the confounding potential sources of these types of wastes, in 1993 DOE estimated that 2,552 Greater-Than-Class-C low-level waste fixed-gauge and X-ray fluorescence sealed sources (general licensees) and 7,582 sealed sources (for example, calibration, medical, well logging sources) were used and stored by private industry at hundreds of locations in the United States (DOE 1994d, all).

As this example illustrates, a meaningful analysis would need to consider the sites, or combination of sites, at which these waste types are currently in use and storage. The analytic approach used to construct the regional representative sites for which the continued storage of spent nuclear fuel and high-level radioactive waste was evaluated would not apply to the hundreds of additional locations associated with Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

For the spent nuclear fuel and high-level radioactive waste analysis in this EIS (see Appendix K, Section K.2.1), DOE collected information from published sources for each of the 77 sites where spent nuclear fuel and high-level radioactive waste is located and, to simplify the analysis, divided the country into five regions. The Department then configured a single hypothetical site in each region (see Appendix K, Section K.2.1.6), which enabled it to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on forecast interactions of the environment (rainfall, freeze-thaw cycle) with the engineered barrier (concrete storage modules).

Environmental information at the hundreds of sites in which Greater-Than-Class-C and Special-Performance-Assessment-Required wastes are in use and storage is not readily available and DOE could not obtain it without an exorbitant commitment of resources. Relevant environmental evaluations such as those prepared by the Nuclear Regulatory Commission for operating commercial nuclear powerplants or spent nuclear fuel storage installations are not available for most of the locations at which these waste types are in use or storage. Further, the manner in which Greater-Than-Class-C and Special-Performance-Assessment-Required low-level wastes are stored varies by waste types, and the great variety of storage methods could not be simplified for analytical purposes without distorting the resulting potential environmental impacts.

Even if such information were gathered and the means of storage could be reduced by the use of simplifying assumptions, the results of the analysis (the impacts) would tend to reinforce the results of the impact analysis performed for the Module 1 inventory. That is, short-term impacts such as those to socioeconomics and land use would not increase appreciably, but health effects probably would increase over the long term because workers and the public would be exposed to these waste types in addition to spent nuclear fuel and high-level radioactive waste at the many locations across the United States.

7.3.1 SHORT-TERM IMPACTS IN THE YUCCA MOUNTAIN VICINITY

Candidate materials would not be transported to the repository. Therefore, impacts from Module 1 would be the same at the Yucca Mountain site as those presented in Section 7.1.

7.3.2 SHORT- AND LONG-TERM IMPACTS AT COMMERCIAL AND DOE SITES

7.3.2.1 Land Use and Ownership

Under Scenario 1 (long-term institutional control), as discussed in Section 7.2.1.1, the land required for storage facilities typically would be a few acres. For the Module 1 inventory, the analysis assumed that the land required would increase, on average, by about 60 percent (the ratio of Proposed Action and Module 1 inventories). This additional land requirement [less than 0.04 square kilometer (10 acres) per site] would represent a small percentage of the land currently available at the sites; therefore, the incremental impacts on land use would be minimal but larger than those for the Proposed Action facilities. These storage facilities would be on land currently owned by DOE or a utility and, therefore, would be unlikely to affect land ownership.

Under Scenario 2 (assumption of no effective institutional control after about 100 years), as discussed in Section 7.2.2.1, without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate, eventually contaminating the land surrounding the storage facilities and rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The additional inventories of Module 1 probably would increase the concentrations of radioactive materials in the soils and the size of the affected areas over those expected for the Proposed Action inventory. As with the Proposed Action, these concentrations and areas would be impossible to estimate but even with the additional inventories of Module 1, DOE believes it would involve less than several hundred acres at each of the 77 sites.

In addition, as with the Proposed Action, because Scenario 2 assumes no effective institutional control after approximately 100 years, there would not be an orderly conversion of land use and ownership to other uses or ownership. Therefore, the potential for members of the public to move onto storage facility lands with Module 1 inventories would be unchanged from that expected for the Proposed Action.

7.3.2.2 Air Quality

As discussed in Section 7.2.1.2, under Scenario 1 best management practices and effective monitoring procedures would ensure that contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutants emissions and Part 50 for air quality standards). In addition, DOE expects that these controls would be effective with the additional inventories of Module 1. Therefore, air quality under Scenario 1, Module 1 would not be adversely affected during routine operations.

As discussed in Section 7.2.1.2, during the construction of replacement facilities, exhaust from construction vehicles would temporarily increase local concentrations of hydrocarbons, carbon monoxide, and oxides of nitrogen for a few years during each 100 years. DOE expects that these temporary increases in particulate matter resulting from construction activities would persist for slightly longer periods because of the additional facilities required to store the additional inventories of Module 1. However, mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. As with the Proposed Action, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Therefore, although adverse air quality impacts during construction would be slightly higher for the Module 1 inventory, DOE expects them to be minimal and transient.

The Module 1 air quality impacts under Scenario 2, as discussed in Section 7.2.2.2, would be minimal because even degraded facilities would limit the release of radioactive particulate material to the atmosphere.

7.3.2.3 Hydrology

7.3.2.3.1 *Surface Water*

For Scenario 1, as discussed in Section 7.2.1.3.1, under long-term institutional control, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent release, contaminants would not reach surface-water systems. These controls and monitoring procedures would be effective for the additional inventories of Module 1. Therefore, as with the Proposed Action inventory, surface-water quality would not be adversely affected by routine operations.

For long-term impacts from Scenario 2, after about 100 years when there is an assumption of no effective institutional control, the Module 1 contaminants could enter surface water via stormwater runoff from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public expected from these additional surface water contaminants resulting from the Module 1 inventory.

7.3.2.3.2 *Groundwater*

Under Scenario 1, Module 1 groundwater impacts from the storage of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste would be minimal because best management practices such as spill prevention and cleanup plans and procedures and effective effluent monitoring procedures would ensure that inadvertent contaminant releases did not reach groundwater.

In addition, although the analysis assumed that the average square footage of storage facilities would increase by about 60 percent for the additional Module 1 inventory, the shallow foundations of these surface structures would not disturb groundwater systems. Some additional DOE storage facilities would be subsurface structures for which construction could require minimal dewatering of the groundwater aquifer. However, the larger square footage of the Module 1 structures would be relatively small (a few acres) in relation to the size of the aquifer, so no adverse impacts would result from dewatering activities.

For long-term impacts from Scenario 2, Module 1 contaminants would be likely to enter the underlying groundwater from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public from these additional groundwater contaminants resulting from the Module 1 inventory.

7.3.2.4 Biological Resources and Soils

For Scenario 1, as discussed in Section 7.2.1.4, under long-term institutional control, impacts to biological resources or soils from the construction every 100 years and operation of the storage facilities would be minimal for the expanded Module 1 inventory. The facilities necessary to store the expanded Module 1 inventory would be fenced to keep wildlife out and replacement facilities would be constructed on previously disturbed soil. In addition, as with the Proposed Action, spills would be contained and cleaned up immediately, thus minimizing the area of soil affected.

For long-term impacts from Scenario 2, the analysis assumed that the potential for individual animals to be exposed to radiation at the storage sites would increase in proportion to the increased Module 1 inventory in comparison to the Proposed Action inventory (approximately 60 percent). While the increased contaminant exposure could have negative effects, including death, on individual animals, adverse impacts to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Contamination of soils at the storage facilities by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material would be likely to increase in proportion to the increase in Module 1 inventory. Appendix K, Section K.2.4, discusses impacts to members of the public from eating food grown in contaminated soils or livestock fed on such soils.

7.3.2.5 Cultural Resources

For Scenario 1, the analysis assumed that the Module 1 replacement of spent nuclear fuel and high-level radioactive waste storage facilities would increase by about 60 percent over the Proposed Action. However, these additional facilities would generally be on undeveloped land owned by DOE or the commercial utilities in rural areas. As with the Proposed Action, the size of the additional facilities and supporting infrastructure would be small enough that the facility probably would avoid known cultural resources. In addition, if previously unknown archaeological sites, human remains, or funerary objects were uncovered during construction, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources. Therefore, construction and operations would not affect cultural resources.

For long-term impacts from Scenario 2, construction and operation for about the first 100 years would be as described for Scenario 1. After this time, no construction or operation activities would occur at the generating sites; therefore, cultural resources would not be adversely affected.

7.3.2.6 Socioeconomics

For Scenario 1, the total staff required at 77 sites to monitor, maintain, and replace the Module 1 facilities would increase from about 700 for the Proposed Action inventory of 70,000 MTHM to more than 800 for the Module 1 inventory of 105,000 MTHM (Orthen 1999, Table 6). This increase is approximately equivalent to adding no more than two individuals at each of the 77 sites. Therefore, the additional storage requirements of the Module 1 inventory would be unlikely to affect socioeconomic factors such as infrastructure and regional economy.

For long-term impacts from Scenario 2, because there is an assumption of no effective institutional control after about 100 years, there would be no workers for either the Proposed Action or Module 1 inventories. Therefore the Module 1 socioeconomic impacts would be essentially the same as those for the Proposed Action for the first 100 years, but after that approximately 800 jobs would be lost. Because these jobs would be spread over 72 commercial and 5 DOE sites (about 10 jobs per site), socioeconomic impacts would be very small for a given region.

7.3.2.7 Occupational and Public Health and Safety

7.3.2.7.1 *Nonradiation Exposures*

For Scenario 1, Module 1, as with the Proposed Action, maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with Occupational Health and Safety Administration and National Institute of Occupational Safety and Health requirements (29 CFR).

Worker exposures to industrial nonradioactive hazardous materials during construction and operation of the storage facilities would be minimized through administrative controls and design features such that exposures would remain below hazardous levels.

For long-term impacts from Scenario 2, the increased inventory of Module 1 would be likely to result in a proportional increase in concentrations of uranium and other toxic materials (such as chromium) in the groundwater and surface waters at the storage sites. However, these concentrations would remain extremely low and would not result in adverse human health impacts.

7.3.2.7.2 *Industrial Hazards*

For Scenario 1, as discussed in Section 7.2.1.7.2, the majority of the industrial accidents would occur as a result of surveillance (about 94 percent) and construction tasks. Operations tasks would contribute less than 0.001 percent of the total number of accidents. Therefore, to estimate the number of industrial accidents that would be likely to occur at the storage sites for the Module 1 inventory, the number of additional concrete storage modules required to store the additional inventory was calculated.

For Module 1 during the approximately 100-year construction and operation cycle (2002 to 2116), about 80,000 full-time equivalent work years would be required to maintain about 11,000 concrete storage modules and 8 below-grade storage vaults at the 77 sites (Orthen 1999, Table 1). Based on this level of effort, as listed in Table 7-10, about 2,800 industrial safety incidents would be likely, resulting in about 1,200 lost workday cases and 3 fatalities (an average of about 1 fatality every 30 years).

In addition, for Module 1, Table 7-10 indicates about 410,000 projected industrial safety incidents, of which about 180,000 would be lost workday cases and 490 would involve fatalities (an average of about 1 fatality every 20 years or about 1 every 1,600 years at each of the 77 sites). Surveillance tasks would provide about 94 percent of the total worker level of effort, construction tasks would provide nearly all of the remaining 6 percent, and operations tasks would provide less than 0.001 percent.

Table 7-10. Estimated Module 1 industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900-year period of analysis under Scenario 1.[a]

Industrial safety impacts	Short-term (100 years)[b] construction and operation (2002-2116)	Long-term (9,900 years)[c] construction and operation (2116-12010)
Total recordable cases	2,800	410,000
Lost workday cases	1,200	180,000
Fatalities	3	490

a. Source: Orthen (1999, Tables 6 and 7).

b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and maintenance.

c. Period from 100 to 10,000 years.

7.3.2.7.3 *Radiation Exposures*

For Scenario 1, radiation exposures to offsite populations, involved workers, and noninvolved workers would increase because of the additional Module 1 inventory and the construction of additional facilities required to store the materials. The analysis assumed that radiation exposures to offsite and noninvolved worker individuals would increase by the ratio of the Module 1 inventory to the Proposed Action inventory, a factor of about 1.7. Radiation dose rates for the involved maximally exposed worker (construction) would not increase because of the self-shielding effect of the concrete storage modules. Table 7-11 lists radiological human health impacts resulting from the Module 1 inventory.

Table 7-11. Estimated Module 1 radiological human health impacts for Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation (2002-2116)	Long-term (9,900 years) construction[b] and operation (2116-12010)
Population[c]		
MEI[d] (millirem per year)	0.34	0.10
Dose[e] (person-rem)	1,400	8,800
LCFs[f]	0.70	4.4
Involved workers[g]		
MEI[h] (millirem per year)	170	50
Dose (person-rem)	4,700	41,000
LCFs	1.9	16
Noninvolved workers[i]		
MEI[j] (millirem per year)	23	0[k]
Dose (person-rem)	61,000	0[k]
LCFs	25	0[k]

a. Source: Adapted from NRC (1991, all); Orthen (1999, all).
b. Assumes construction of 11,000 concrete storage modules, 1 above-grade vault, and 8 below-grade vaults at 77 sites (Orthen 1999, Table 1) every 100 years.
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the 9,900-year long-term analysis period [estimated using Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (NRC 1991, page 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer per rem for workers and members of the public, respectively (NCRP 1993b, page 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (NRC 1991, pages 23 to 25). For this analysis, the involved worker population would be about 1,600 individuals (800 individuals at any one time) at 77 sites over 100 years (Orthen 1999, Table 6). This population would grow to more than 190,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (NRC 1991, page 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposure until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (NRC 1991, page 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

As listed in Table 7-11, the estimated dose to the hypothetical maximally exposed offsite individual for the Module 1 inventory during the operational period between 2002 and 2116 would be about 0.34 millirem per year [adapted from NRC (1991, page 22)]. For the remaining 9,900 years of the analysis period, the dose to the hypothetical maximally exposed individual would decrease to about 0.10 millirem per year because of radioactive decay of the source material. During about the first 100 years, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000073, an increase over the lifetime natural fatal cancer incidence rate of 0.0031 percent. During the remaining 9,900 years of the analysis period, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000022, an increase over the lifetime natural fatal cancer incidence rate of 0.00092 percent.

For the short-term impacts, over about the first 100 years the offsite exposed population of approximately 140,000 would be likely to receive a total collective dose of 1,400 person-rem (adjusted for radioactive decay). This dose could result in 0.70 latent cancer fatality in addition to the 33,000 fatal cancers likely in the exposed population from all other causes. This represents an increase of about 0.0021 percent over

the estimated number of cancer fatalities that would occur in the exposed population from all other causes.

For the long-term impacts from Scenario 1, the radiation dose of 8,800 person-rem from the storage facilities could result in an additional 4.4 latent cancer fatalities in the surrounding population of about 14 million. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, an increase of 0.00013 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be a construction worker involved with construction and loading of replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour (unchanged from the Proposed Action) and an average exposure time of 1,500 hours per year, this construction worker would receive about 170 millirem per year. During about the first 100 years, this dose could result (over three years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.083 percent over the natural fatal cancer incidence rate. During the remaining 9,900 years of the analysis period, the dose could result (over three years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060, an increase over the natural fatal cancer incidence rate of 0.025 percent.

For the involved worker population of 1,600 individuals, approximately 380 would be likely to contract a fatal cancer from some cause other than occupational exposure. In the involved population of 1,600 storage facility workers (during the first 100 years), the collective dose of 4,700 person-rem (corrected for radioactive decay) between 2002 and 2116 could result in 1.9 additional latent cancer fatalities (Orthen 1999, Table 6), which would result in an increase of 0.51 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the involved estimated worker population of more than 190,000 would receive a collective dose of about 41,000 person-rem (corrected for radioactive decay). This dose could result in 16 latent cancer fatalities in addition to the 45,000 cancer fatalities that would be likely in the exposed population from all other causes. These additional cancers would represent an increase of 0.036 percent over the natural incidence rate of fatal cancers.

The estimated Module 1 collective dose to noninvolved workers at a nuclear powerplant from the Module 1 inventory would be about 27 person-rem per year [adapted from NRC (1991, page 24)] for the protected area workforce of 1,200 individuals (NRC 1991, page 26) at the two-unit station at Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 23 millirem per year. Over a 50-year career, this exposure (corrected for radioactive decay) could result in an increase in the lifetime risk of contracting a fatal cancer of 0.00032. This incremental increase in risk would represent an increase of 0.13 percent over the incidence of fatal cancers from all other causes.

In the total noninvolved worker population of 80,000 powerplant workers (all sites), the estimated Module 1 collective dose of 61,000 person-rem (corrected for decay) between 2002 and 2116 could result in 25 additional latent cancer fatalities. This increase represents about an 0.13-percent increase over the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

After about 100 years, Scenario 2 assumes no effective institutional control of the 77 sites and assumes that the storage facilities would be abandoned. Therefore, there would be no health risk for workers during that period. For the long-term impacts from Scenario 2, the analysis estimated human health impacts to the public on a regional basis (Poe 1999, page 15). The estimated total population dose would increase from 6.6 million person-rem to about 7.3 million person-rem, resulting in an increase in the number of latent cancer fatalities from about 3,300 to almost 3,700 over the 9,900-year analysis period. Appendix K (Sections K.2.4.1 and K.3.1) contains details of the Proposed Action analysis.

7.3.2.8 Accidents

For Scenario 1, both short- and long-term accident consequences for the additional inventory of Module 1 would be bounded by the severe seismic event and could result in slightly higher impacts than those predicted for the Proposed Action inventory. However, this accident scenario would probably produce only minor radiological impacts to persons in the immediate vicinity of the storage facility.

For Scenario 2, the long-term impacts for Module 1 would be the same as those for the Proposed Action (see Section 7.2.2.7) because only a single concrete storage module would be affected, regardless of inventory.

7.3.2.9 Noise

For Scenario 1, noise levels for the Module 1 inventory should not be noticeably greater than those for the Proposed Action. Therefore, the noise would not adversely affect the hearing of facility workers or frighten wildlife from the area.

For the long-term impacts from Scenario 2, as with the Proposed Action, no noise would emanate from the facilities; therefore, no adverse impacts would occur. For about the first 100 years, noise levels would be the same as those for Scenario 1.

7.3.2.10 Aesthetics

As for the Proposed Action, Scenario 1 impacts to aesthetic or scenic resources from storage facilities resulting from the Module 1 inventory would be unlikely. Though the inventory would be larger than that for the Proposed Action, Module 1 would still require only two adjacent locations at each site. Every 100 years, a new facility would be constructed on the idle site, and the storage containers would be transferred. The old facility would be demolished and the site would remain idle for the next 100 years.

For the long-term impacts from Scenario 2, aesthetics would not change until facilities began to degrade, at which time the aesthetic value of the sites would change.

7.3.2.11 Utilities, Energy, and Materials

For Scenario 1, decommissioning and reclamation activities every 100 years associated with the increased number of concrete storage modules required for the Module 1 inventory would consume slightly more diesel fuel, gasoline, and materials than those for the Proposed Action. However, as with the Proposed Action, much equipment and many materials would be salvaged and recycled. DOE would recycle building materials as practicable. Minimal surveillance activities would require some gasoline. Therefore, the increased Module 1 inventory would not adversely affect the utility, energy, or material resources of the region or the country.

For the long-term impacts from Scenario 2, as with the Proposed Action, DOE would not use utilities, energy, or materials after about 100 years and, therefore, impacts to these resources would be unlikely.

7.3.2.12 Waste Management

Under Scenario 1, the construction of new facilities and the demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would

generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during periods of construction. The greatest amount of waste would be generated during the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 1.4 million cubic meters (1.8 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister failed while in storage. The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to a single disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

For Scenario 2, demolition activities would terminate after about 100 years and, therefore, no additional long-term waste management impacts would be likely after this period.

7.3.2.13 Environmental Justice

For Scenario 1, the potential impacts of continued storage of the Module 1 inventory with institutional control would be minimal. Therefore, minority or low-income populations would not be disproportionately or adversely affected.

For the long-term impacts from Scenario 2, the increased number of facilities required to store the Module 1 inventory could adversely affect the nearby public to a degree greater than that for the Proposed Action inventory. As with the Proposed Action inventory, nearby minority or economically disadvantaged communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns vary for minority or low-income populations, members of these populations could be exposed to greater than average doses. The result of differing potentials for exposure could result in disproportionately high and adverse impacts to minority or low-income populations.

7.3.2.14 Traffic and Transportation

For Scenario 1, the estimated number of workers commuting to and from work would increase from about 700 to about 800 (Orthen 1999, Table 7). The analysis assumed that the number of personnel required for round-the-clock surveillance would not increase but would remain at two individuals per shift per site.

The estimated number of traffic fatalities, which DOE calculated using the assumptions of Section 7.2.1.14, would be approximately 7 for the first 100 years and would increase from about 730 to about 900 for the remaining 9,900 years (Orthen 1999, Table 7).

For about the first 100 years, there would be no fatalities or latent cancer fatalities from exhaust emissions because there would be no construction or demolition of facilities. For the remaining 9,900 years, trucks would travel over 2.2 billion kilometers (1.4 billion miles), resulting in approximately 49 prompt traffic fatalities and 0.16 latent cancer fatality from vehicle exhaust emissions (Orthen 1999, Table 7).

The long-term impacts from Scenario 2 would be the same as those estimated for the first 100 years under Scenario 1 for Module 1. After the first 100 years, there would be no traffic or transportation-related impacts because all activity would cease.

7.3.2.15 Sabotage

For Scenarios 1 and 2, the risk of intruder access at each of the 77 sites would be essentially the same for Module 1 as for the Proposed Action inventory because the number of sites would remain the same. Therefore, the difficulty of maintaining 77 sites over 100 or 10,000 years also would remain essentially unchanged.

8

Cumulative Impacts

8. CUMULATIVE IMPACTS

The Council on Environmental Quality regulations that implement the procedural provisions of the National Environmental Policy Act of 1969, as amended (42 USC 4321 *et seq.*), define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively important actions taking place over a period of time. An evaluation of cumulative impacts is necessary to an understanding of the environmental implications of implementing the Proposed Action and is essential to the development of appropriate mitigation measures and the monitoring of their effectiveness.

This chapter evaluates the environmental impacts of repository activities coupled with the impacts of other Federal, non-Federal, and private actions. As part of this process, the chapter includes a detailed analysis of nuclear materials in need of permanent disposal in excess of those evaluated in the Proposed Action. It describes and evaluates these waste quantities, referred to as Inventory Modules 1 and 2, evaluated in terms of their environmental impacts in comparison with those of the Proposed Action impacts. The evaluation of these inventories provides sufficient information for future actions and decisionmaking on inventory selection. This chapter evaluates cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts following repository closure. It also evaluates cumulative transportation impacts from the shipment of spent nuclear fuel and high-level radioactive waste to the repository and of other material to or from the repository. The analysis of cumulative transportation impacts includes the possible construction and operation in Nevada of a branch rail line, or of an intermodal transfer station along with highway improvements for heavy-haul trucks. In addition, the analysis considers cumulative impacts from the manufacturing of disposal containers and shipping casks.

The cumulative impact analysis in this chapter includes as a reasonably foreseeable future action the disposal in the proposed Yucca Mountain Repository of the total projected inventory of commercial spent nuclear fuel, U.S. Department of Energy (DOE) spent nuclear fuel, and high-level radioactive waste, as well as the disposal of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste. The total projected inventory of spent nuclear fuel and high-level radioactive waste is more than the 70,000 metric tons of heavy metal (MTHM) considered for the Proposed Action. Its emplacement at Yucca Mountain would require legislative action by Congress unless a second licensed repository was in operation.

There were several reasons to evaluate the potential for disposing of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste at Yucca Mountain as reasonably foreseeable actions. First, because both materials exceed Class C limits for specific radionuclide concentrations as defined in 10 CFR Part 61, they are generally unsuitable for near-surface disposal. Second, the U.S. Nuclear Regulatory Commission specifies in 10 CFR 61.55(a)(2)(iv) the disposal of Greater-Than-Class-C waste in a repository unless the Commission approved of disposal elsewhere. Finally, during the scoping process for this environmental impact statement (EIS), several commenters requested that DOE evaluate the disposal of other radioactive waste types that might require isolation in a repository. The disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require a determination by the Nuclear Regulatory Commission that these wastes require permanent isolation. In addition to spent nuclear fuel, high-level radioactive waste, surplus plutonium, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (materials such as depleted uranium), other radioactive wastes could be considered in the future for disposal in the Yucca Mountain Repository.

In general, the analysis of cumulative impacts in this chapter follows the process recommended in the Council on Environmental Quality's handbook *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997, all). This process includes the identification, through research and consultations, of Federal, non-Federal, and private actions with possible effects that would be coincident with those of the Proposed Action on resources, ecosystems, and human communities. Coincident effects would be possible if the geographic and time boundaries for the effects of the Proposed Action and past, present, and reasonably foreseeable future actions overlapped. Using the methods and criteria described in Chapters 4, 5, and 6 of this EIS and their supporting appendixes, DOE assessed the potential cumulative impacts of coincident effects.

This chapter has five sections. Section 8.1 identifies and analyzes past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. Sections 8.2 and 8.3 present the analyses of cumulative short-term (the period before the completion of repository closure) and long-term (the first 10,000 and first 1 million years following closure) impacts, respectively, in the proposed Yucca Mountain Repository region. Section 8.4 describes cumulative transportation impacts, nationally and in Nevada. Section 8.5 addresses cumulative impacts associated with the manufacturing of disposal containers and shipping casks.

8.1 Past, Present, and Reasonably Foreseeable Future Actions

This section identifies past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. It describes these actions and their relationships to the Proposed Action that could result in cumulative impacts (see Table 8-1 for a summary). Sections 8.2 through 8.5 present the cumulative impacts from the past, present, and reasonably foreseeable future actions identified in this section.

8.1.1 PAST AND PRESENT ACTIONS

The description of existing (baseline) environmental conditions in Chapter 3 includes the impacts of most past and present actions on the environment that the Proposed Action would affect. This includes site characterization activities at Yucca Mountain. The impacts of past and present actions are, therefore, generally encompassed in the Chapter 4, 5, and 6 analyses of potential environmental impacts of the Proposed Action because the baseline for these analyses is the affected environment described in Chapter 3.

Two past actions that are not addressed in the Chapter 3 environmental baseline were identified for inclusion in the cumulative impact analysis in Sections 8.2, 8.3, and 8.4—past DOE activities at the Nevada Test Site (nuclear weapons testing, etc.) and past disposal of low-level radioactive waste at the Beatty Waste Disposal Area. Resources identified where past Nevada Test Site activities could add to impacts from the Proposed Action include air quality, groundwater, public health and safety, and transportation. For the Beatty Waste Disposal Site, the analysis included potential cumulative impacts from past transportation of waste to the Beatty site and from potential groundwater contamination.

8.1.2 REASONABLY FORESEEABLE FUTURE ACTIONS

This section describes the reasonably foreseeable future actions that the cumulative impacts analysis considered. The analysis included cumulative impacts from the disposal in the proposed repository of all projected spent nuclear fuel and high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste as reasonably foreseeable future actions (Inventory Modules 1 and 2; see Section 8.1.2.2). Sections 8.1.2.3 and 8.1.2.4 describe other Federal, non-Federal, and private actions that could result in cumulative impacts. DOE did not analyze the No-Action

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 1 of 2).

Action	Potential cumulative impacts			
	Impacts in the Yucca Mountain Repository region			
Name and description	Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Past and present actions[b]				
Nevada Test Site				
Nuclear weapons testing, waste management, etc.	None	Air quality, groundwater, and public health and safety	Occupational and public radiological health and safety	None
Beatty Waste Disposal Area				
Low-level radioactive waste disposal	None	Groundwater	Occupational and public radiological health and safety	None
Reasonably foreseeable future actions				
Inventory Module 1[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste in the proposed Yucca Mountain Repository	Same resources as the Proposed Action	Same resources as the Proposed Action	Same resources as the Proposed Action	Same resources as the Proposed Action
Inventory Module 2[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class C waste and Special-Performance-Assessment-Required waste, in the proposed Yucca Mountain Repository	Same resources as the Proposed Action	Same resources as the Proposed Action	Same resources as the Proposed Action	Same resources as the Proposed Action
Nellis Air Force Range				
National testing and training for military equipment and personnel	The Air Force is proposing no substantial new activities in the future at the Nellis Air Force Range.	The Air Force is proposing no substantial new activities in the future at the Nellis Air Force Range.	The Air Force is proposing no substantial new activities in the future at the Nellis Air Force Range.	The Air Force is proposing no substantial new activities in the future at the Nellis Air Force Range.
Nevada Test Site				
Defense (stockpile stewardship and management, material disposition, nuclear emergency response), waste management, environmental restoration, nondefense research and development, work for others	Air quality, groundwater, socioeconomics, public health and safety. (Note: The accident analysis of potential external events in Appendix H addresses the effects of possible future resumption of nuclear weapons tests).	Groundwater and public health and safety	Occupational and public radiological health and safety	None

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 2 of 2).

Action	Potential cumulative impacts			
	Impacts in the Yucca Mountain Repository region			
Name and Description	Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Reasonably foreseeable future actions (continued)				
DOE Complex-Wide Waste Management Activities Affecting the Nevada Test Site				
Treatment, storage, and disposal of low-level radioactive waste, mixed waste, transuranic waste, high-level radioactive waste, and hazardous waste from past and future nuclear defense and research activities	None[d]	Groundwater and public health and safety	Occupational and public radiological health and safety	None
Low-Level Waste Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site near Caliente	None	None	Same resources as the Proposed Action (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Timbisha Shoshone Reservation				
Creation of a discontiguous reservation in eastern California and southwestern Nevada for people of the Timbisha Shoshone Tribe	None	None	Water consumption, public safety, environmental justice	None
Cortez Pipeline Gold Deposit Projects				
Continued operation and potential expansion of a gold mine and processing facility	None	None	Land use and ownership (Carlin rail corridor)	None
Apex Bulk Commodities Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for copper concentrate near Caliente	None	None	Same resources as the Proposed Action (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Shared use of a DOE branch rail line				
Increase in rail operations and traffic resulting from rail service options for nearby mine operators and communities	None	None	Same resources as the Proposed Action	None

a. In addition to the specific actions identified in Section 8.1 and summarized in this table, the cumulative impacts for national transportation consider the occupational and public radiological health impacts of other past, present, and reasonably foreseeable future shipments of radioactive material.

b. The impacts of most past and present actions are included in the existing environmental baseline described in Chapter 3 and, therefore, are generally encompassed in the analysis of potential impacts of the Proposed Action in Chapters 4, 5, and 6. This includes site characterization activities at Yucca Mountain.

c. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the cumulative impacts from Inventory Module 1 are generally considered the same as those from Inventory Module 2.

d. DOE waste management activities at the Nevada Test Site are included above for the continuation of waste management activities at current levels, plus additional wastes that could be received as a result of decisions based on the Waste Management Programmatic EIS (DOE 1997b, all). This includes cumulative impacts of transportation and disposal.

Alternative for cumulative impacts. Chapter 7, Section 7.3, describes the cumulative impacts for the No-Action Alternative. Chapters 2 and 7 contain details on this alternative and also on continued storage of the material at its current locations or at one or more centralized location(s). Interim storage is not analyzed for cumulative impacts because, as stated in Chapter 7, the potential for such storage is highly uncertain.

DOE gathered information on Federal, non-Federal, and private actions to identify reasonably foreseeable future actions that could combine with the Proposed Action to produce cumulative impacts. The types of documents reviewed included other EISs, resource management plans, environmental assessments, Notices of Intent, Records of Decision, etc. Consultations with Federal agencies, state and local agencies, and Native American tribes (see Appendix C) also contributed to the information used in the cumulative impact analysis.

8.1.2.1 Inventory Modules 1 and 2

Under the Proposed Action, DOE would emplace in the proposed Yucca Mountain Repository as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. Of the 70,000 MTHM, approximately 63,000 MTHM would be commercial spent nuclear fuel. The remaining 7,000 MTHM would consist of approximately 2,333 MTHM of DOE spent nuclear fuel and approximately 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste. To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used an equivalence of 0.5 MTHM per canister of defense high-level radioactive waste. DOE has consistently used the 0.5-MTHM-per-canister equivalence since 1985. Using a different approach would change the number of canisters of high-level radioactive waste analyzed. Regardless of the number of canisters, the impacts from the entire inventory of high-level radioactive waste are analyzed in this chapter. In addition, the 70,000 MTHM inventory would include 50 metric tons (55 tons) of surplus plutonium as spent mixed-oxide fuel or immobilized plutonium.

Inventory Modules 1 and 2 represent the reasonably foreseeable future actions of disposing of all projected commercial and DOE spent nuclear fuel and all high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed repository (see Figure 8-1). Under Inventory Module 1, DOE would emplace all projected commercial spent nuclear fuel (about 105,000 MTHM), all DOE spent nuclear fuel (about 2,500 MTHM), and all high-level radioactive waste (approximately 22,280 canisters). Inventory Module 2 includes the Module 1 inventory plus other radioactive material that could require disposal in a monitored geologic repository (commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste). The estimated quantities of these other wastes are about 2,100 cubic meters (74,000 cubic feet) and about 4,000 cubic meters (140,000 cubic feet), respectively. Appendix A contains further details on these inventories.

The following paragraphs summarize the differences in repository facilities and operations to receive, package, and emplace the additional materials in Inventory Module 1 or 2. The information on Modules 1 and 2 in this section is from TRW (1999a,b,c, all) unless otherwise noted. Table 8-2 summarizes the increased number of shipments that would be required to transport the Module 1 or 2 inventory to the repository. As for the Proposed Action, the estimated numbers of shipments were based on the characteristics of the materials, shipping capabilities at the commercial nuclear sites and DOE facilities, the assumption that there would be one shipping cask per truck or railcar (a train would normally use multiple rail cars and ship more than one cask), various cask designs, and the transportation mode mix (mostly legal-weight truck or mostly rail). Appendix J contains additional details on Inventory Module 1 and 2 transportation requirements.

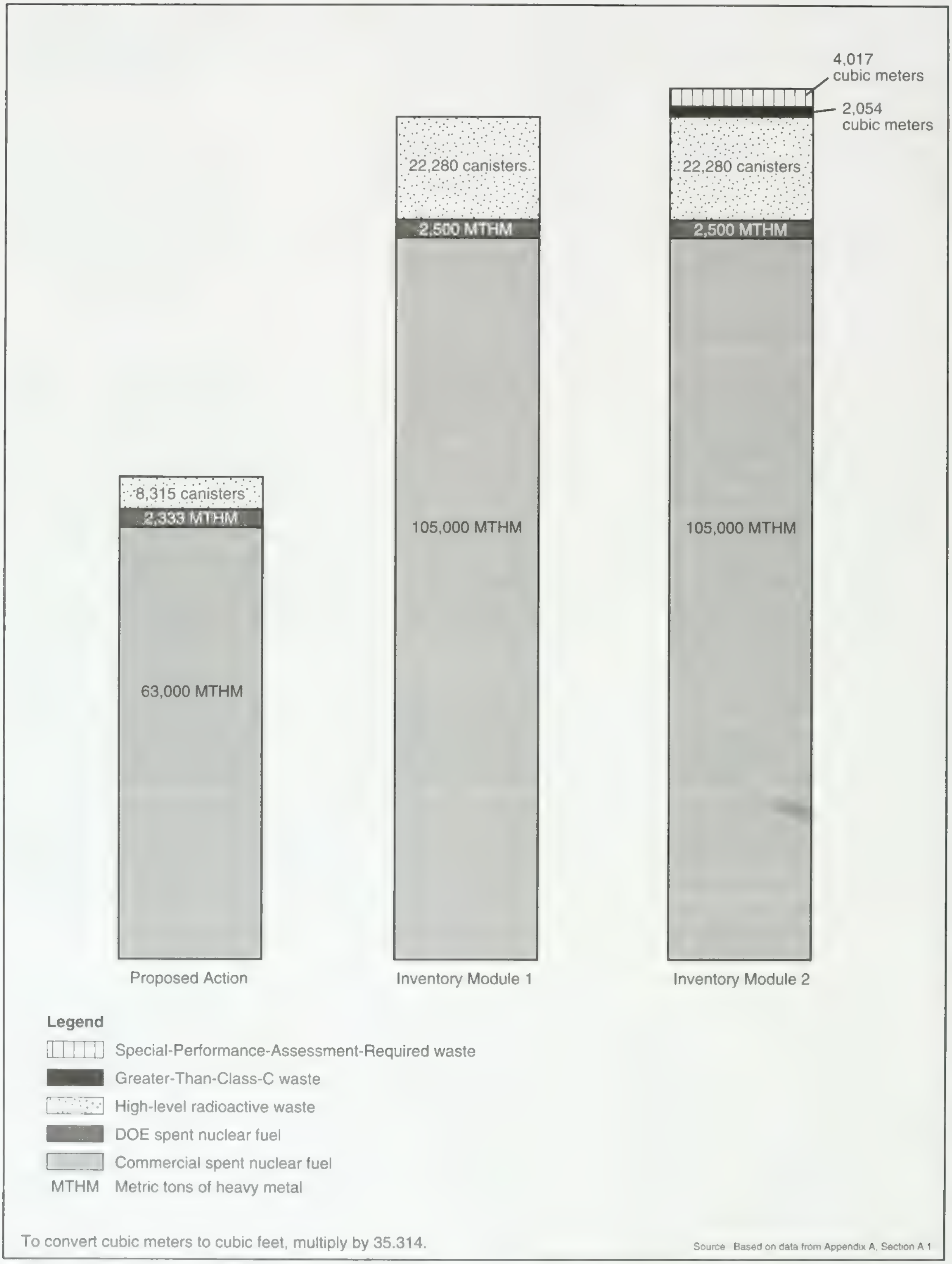


Figure 8-1. Proposed Action, Module 1, and Module 2 inventories evaluated for emplacement in a repository at Yucca Mountain.

Table 8-2. Estimated number of shipments for the Proposed Action and Inventory Modules 1 and 2.[a,b]

	Proposed Action				Module 1				Module 2			
	Mostly legal-weight truck		Mostly rail		Mostly legal-weight truck		Mostly rail		Mostly legal-weight truck		Mostly rail	
Material	Truck	Rail[c]	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail	Truck	Rail
Commercial SNF[d]	38,000	0	2,600	8,400	67,000	0	3,700	14,000	67,000	0	3,700	14,000
DOE SNF	3,500	300	0	770	3,700	300	0	800	3,700	300	0	800
HLW[e]	8,300	0	0	1,700	22,000	0	0	4,500	22,000	0	0	4,500
GTCC[f] waste	0	0	0	0	0	0	0	0	1,100	0	0	280
SPAR[g] waste	0	0	0	0	0	0	0	0	2,000	0	0	400
Totals	**50,000**	**300**	**2,600**	**11,000**	**93,000**	**300**	**3,700**	**19,000**	**96,000**	**300**	**3,700**	**20,000**

a. Source: Appendix J, Section J.1.3.1.
b. Totals might differ from sums due to rounding.
c. For this EIS, each combination of a shipping cask and railcar is assumed to be a single shipment.
d. SNF = spent nuclear fuel.
e. HLW = high-level radioactive waste.
f. GTCC = Greater-Than-Class-C.
g. SPAR = Special-Performance-Assessment-Required.

The following are the major differences between the repository facilities and operations for Inventory Modules 1 and 2 and those for the Proposed Action, which are described in Chapter 2:

- The longer time required to receive, package, and emplace the additional spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste, and to close the repository, for Inventory Module 1 or 2 versus that for the Proposed Action. The periods for the various project phases for Inventory Modules 1 and 2 would be the same.

- The need for more subsurface area to emplace about 17,000 to 19,000 waste packages for Inventory Module 1 and about 18,000 to 20,000 waste packages for Module 2 in comparison to about 10,000 to 11,000 waste packages for the Proposed Action (see Table 8-34)

Table 8-3 lists the differences in the expected time sequence for the repository construction, operation and monitoring, and closure phases for the Proposed Action and Inventory Module 1 or 2.

Table 8-3. Expected time sequence (years) of Yucca Mountain Repository phases for the Proposed Action and Inventory Module 1 or 2.[a]

Inventory	Construction phase (2005-2010)	Operation and monitoring phase (2010-2110)				Closure phase (starts in 2110)
		Development[b]	Emplacement	Monitoring	Total	
Proposed Action	5	22	24	76	100[c]	6-15[d]
Module 1 or 2	5	36	38	62	100	13-27[e]

a. Source: TRW (1999b, all); TRW (1998k,m,n,o,p,q,r,s,t,u,v, all); Jessen (1999b, all).
b. Continuing subsurface construction (development) activities are concurrent with emplacement activities.
c. Closure is assumed to begin 100 years following initial emplacement for the Proposed Action and Module 1 or 2 for the evaluation of cumulative impacts.
d. 6, 6, and 15 years for the high, intermediate, and low thermal load scenarios, respectively.
e. 13, 17, and 27 years for the high, intermediate, and low thermal load scenarios, respectively.

The amount of land required for surface facilities would increase only slightly for Inventory Module 1 or 2 from that for the Proposed Action (see Table 8-4). The design and operation of the repository surface facilities for Inventory Modules 1 and 2, including a Cask Maintenance Facility if it was at the Yucca Mountain site, would not differ much from those of the Proposed Action. The rate of material receipt, packaging, and emplacement would be approximately the same and would require an extra 14 years beyond the 24-year emplacement period for the Proposed Action. There would be no difference in the duration of the emplacement period between Inventory Modules 1 and 2 because the surface and subsurface facilities could accommodate the small number of additional shipments and waste packages for Module 2.

Table 8-4. Amount of land disturbed at the proposed Yucca Mountain Repository for the Proposed Action and Inventory Module 1 or 2 (square kilometers).[a,b,c]

	Proposed Action			Module 1 or 2		
Area	High thermal load	Intermediate thermal load	Low thermal load	High thermal load	Intermediate thermal load	Low thermal load
North Portal Operations Area[d]	0.62	0.62	0.62	0.62	0.62	0.62
South Portal Operations Area	0.15	0.15	0.15	0.15	0.15	0.15
Ventilation Shaft Operations Areas	0.02 (2 shafts)	0.02 (2 shafts)	0.06 (5 shafts)	0.02 (2 shafts)	0.04 (3 shafts)	0.06 (5 shafts)
Excavated rock storage area	1.02	1.17	1.15	1.17	1.40	2.00
Totals	**1.82**	**1.97**	**1.98**	**1.97**	**2.21**	**2.83**

a. Source: Jessen (1998, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. The amount of land disturbance in the vicinity of the North Portal would vary slightly among the three packaging scenarios. The 0.62 square kilometer includes the surface facilities at the North Portal Operations Area and roads.

The repository subsurface facilities for Inventory Module 1 or 2 would require about 60 percent more subsurface excavation than the Proposed Action. About 5.0, 7.1, and 17 square kilometers (1,240, 1,750, and 4,200 acres) would be required for the high, intermediate, and low thermal load scenarios, respectively, for Module 1 or 2. This compares to 3.0, 4.25, and 10 square kilometers (740, 1,050, and 2,500 acres) for the high, intermediate, and low thermal load scenarios, respectively, for the Proposed Action (TRW 1999b, all). Additional subsurface area would be needed beyond the one to three blocks for the Proposed Action. DOE would characterize these blocks, which would be adjacent to the blocks identified for the Proposed Action, more fully before their use. The subsurface facilities would not differ between Inventory Modules 1 and 2 because the additional waste packages for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes would be placed between commercial spent nuclear fuel waste packages. There would be no difference in emplacement operations for Inventory Module 1 or 2 from those described for the Proposed Action in Chapter 2. With the exception of the shorter duration after the completion of emplacement (62 rather than 76 years) (see Table 8-3), there would be no difference in monitoring and maintenance activities for Inventory Module 1 or 2 in comparison to the Proposed Action.

Because of the longer tunnels that would require the use of rock or other material to fill and seal the tunnels for Inventory Module 1 or 2, the duration of the closure phase would be longer, 6 to 15 years for the Proposed Action and 13 to 27 years for Module 1 or 2, depending on the thermal load scenario (see Table 8-3). Inventory Module 1 or 2 closure phase activities would not otherwise differ from those described in Chapter 2 for the Proposed Action.

8.1.2.2 Federal Actions

The following paragraphs describe reasonably foreseeable future actions of Federal agencies that could result in cumulative impacts in addition to those from Inventory Module 1 or 2.

Nellis Air Force Range

The Nellis Air Force Range in south-central Nevada (see Figure 8-2) is a national test and training facility for military equipment and personnel. The *Renewal of the Nellis Air Force Range Land Withdrawal Department of the Air Force Legislative Environmental Impact Statement* (USAF 1999, all) addresses the potential environmental consequences of the Air Force proposal to continue the Nellis Air Force Range

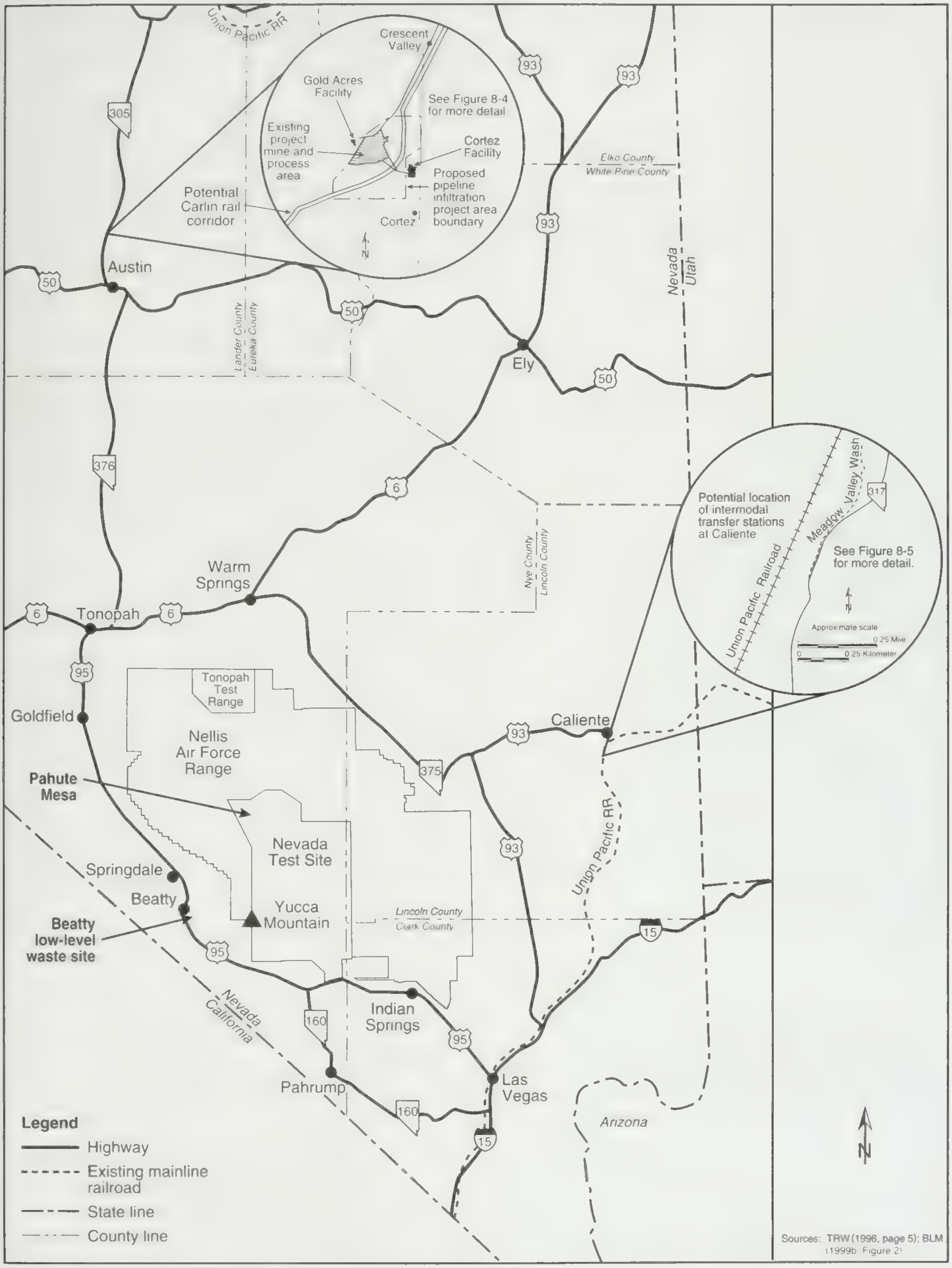


Figure 8-2. Locations of past, present, and reasonably forseeable future actions considered in the cumulative impact analysis.

land withdrawal for military use. The Air Force is proposing no substantial new activities in the future; the descriptions of the affected environment in Chapter 3 and the potential impacts of the Proposed Action in Chapters 4, 5, and 6 include the effects of present activities at the Nellis Air Force Range.

Nevada Test Site

The *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all) examines current and future DOE activities in southern Nevada at the Nevada Test Site, Tonopah Test Range, and sites the Department formerly operated in Nevada. The Record of Decision for that EIS (61 *FR* 65551, December 13, 1996) states that DOE would implement a combination of three alternatives: Expanded Use, No Action (continue operations at current levels) regarding mixed and low-level radioactive waste management, and Alternate Use of Withdrawn Lands regarding public education.

The Expanded Use Alternative incorporates all the activities and operations from ongoing Nevada Test Site programs and increases some of those programs. Activities of the Office of Defense Programs would expand at both the Nevada Test Site and the Tonopah Test Range, primarily in the areas of stockpile stewardship and management, materials disposition, and nuclear emergency response. As part of the Stockpile Stewardship and Management Program, there are continuing subcritical weapons test activities to study aging of weapons components and their reliability after aging. Waste management activities would continue at current levels pending decisions by DOE based on the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DOE 1997b, all). Based on the preferred alternative in the programmatic EIS, this cumulative impact analysis included the additional low-level and mixed waste that could come to the Nevada Test Site. The Environmental Restoration Program would continue, potentially at an accelerated rate, at the Nevada Test Site and all offsite locations. Under the Work for Others Program, military use of the airspace over the Nevada Test Site and the Tonopah Test Range would increase, as would the use of certain lands on the Nevada Test Site by the military for training, research, and development. Public education activities would include the possible construction of a museum that highlights Nevada Test Site testing activities. The Nevada Test Site Development Corporation is considering the VentureStar® program initiative from the Lockheed Martin Corporation for a launch/recovery system that would link with the Kistler Aerospace Satellite launch and recovery project. The VentureStar® program would require two spaceports, a manufacturing and assembly facility, and a payload processing and administrative complex. These activities could occur in Areas 18, 22, and 23, respectively (Figure 8-3). Construction activities could begin in 2002 with an initial launch by 2004. Activities associated with VentureStar® and Kistler could result in the creation of as many as 2,500 jobs, road improvements, power upgrades, and a natural gas supply to the Nevada Test Site. However, there is not enough information at this time to perform a cumulative impacts analysis for this project.

The Nondefense Research and Development Program would continue to support ongoing program operations and pursue new initiatives, such as constructing and operating a solar power production facility (Solar Enterprise Zone facility) at the Nevada Test Site and a proposal by the Kistler Aerospace Corporation to use the Nevada Test Site for launching communication and other commercial and government satellites and recovering reusable launch vehicles.

An analysis of the environmental impacts presented in the Nevada Test Site EIS (DOE 1996f, all) and summarized in the DOE Record of Decision (61 *FR* 65551, December 13, 1996) (including impacts from weapons testing and the VentureStar® Kistler project) identified the following resources for which impacts could overlap in relation to geography and timing with impacts from the proposed repository: air quality, groundwater, socioeconomics, public health and safety, and transportation. The effects on the Yucca Mountain Repository if a decision were made in the future to resume nuclear weapons testing or

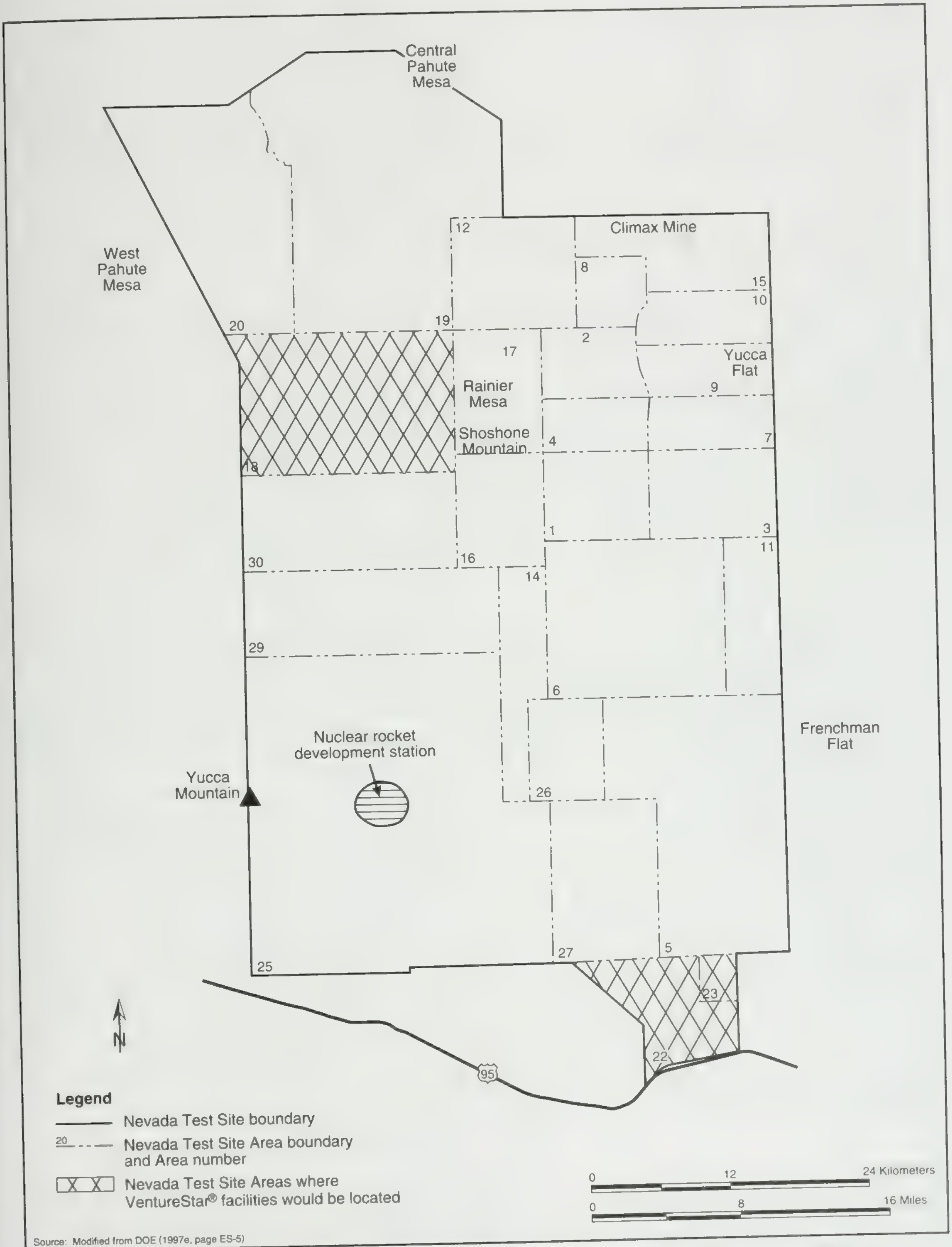


Figure 8-3. Potential locations of proposed cumulative activity associated with VentureStar® at the Nevada Test Site.

from a possible vehicle launch or recovery accident at the proposed VentureStar®/Kistler project are considered in the accident analysis of potential external events in Appendix H.

DOE Waste Management Activities

The Waste Management Programmatic EIS (DOE 1997b, all) evaluates the environmental impacts of managing five types of radioactive and hazardous wastes generated by past and future nuclear defense and research activities at a variety of DOE sites in the United States. The five waste types are low-level radioactive waste, mixed low-level waste (referred to in this EIS as simply mixed waste), transuranic waste, high-level radioactive waste, and hazardous waste. The Waste Management Programmatic EIS provides information to assist DOE with decisions on the management of, and facilities for, the treatment, storage, and disposal of these radioactive, hazardous, and mixed wastes.

Based on the Waste Management Programmatic EIS, DOE will make national, programmatic disposal decisions for both low-level waste and mixed waste. The DOE preferred alternative is to send its low-level radioactive waste and mixed waste to regional disposal sites after it is treated. After consultations with stakeholders, DOE plans to select two or three preferred sites from the following six: Hanford, Idaho National Environmental and Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, Oak Ridge Reservation, and Savannah River Site. DOE could select the Nevada Test Site as a regional disposal site for low-level radioactive waste, mixed waste, or both with about 99 to 100 percent, respectively, of the waste being generated from non-Nevada Test Site generators. DOE waste management actions described in the Waste Management Programmatic EIS would have cumulative transportation impacts and, depending on the selected low-level radioactive waste and mixed waste disposal sites, potential cumulative short- and long-term impacts in the proposed Yucca Mountain Repository region.

In addition, based on the Waste Management Programmatic EIS, DOE will make national, programmatic decisions on the locations at which DOE will store immobilized high-level radioactive waste prior to its disposal at the proposed Yucca Mountain Repository. The DOE preferred alternative is to store its high-level radioactive waste at Hanford, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, and the West Valley Demonstration Project until acceptance at a geologic repository or other facility managed by DOE.

The *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement* (DOE 1997o, Chapter 5) identifies potential cumulative transportation impacts from the shipment of transuranic wastes from DOE sites across the United States, including the Nevada Test Site, to the Waste Isolation Pilot Plant in southeastern New Mexico for disposal.

Low-Level Waste Intermodal Transfer Station

DOE prepared a draft environmental assessment (DOE 1998m, all) on a proposed action to encourage low-level radioactive waste generators and their contractors to use transportation alternatives that would minimize radiological risk, enhance safety, and reduce the cost of waste shipments to the Nevada Test Site. However, DOE determined that there was no decision for it to make relative to transportation of low-level radioactive waste that would require a National Environmental Policy Act analysis, and therefore no longer plans to issue a National Environmental Policy Act document. DOE will publish a technical report which provides its low-level radioactive waste generators with a comparative risk analysis of alternative highway routes and intermodal transportation facilities.

Road improvements to accommodate legal-weight trucks and the construction of a rail siding or spur on a 0.02-square-kilometer (5-acre) site 1.2 kilometers (0.75 mile) south of Caliente would be needed for the low-level radioactive waste intermodal transfer station. Lifting equipment (crane or forklift) would transfer containers of low-level radioactive waste from railcars to trucks for transport to the Nevada Test

Site. Based on a 10-year average estimate of low-level waste volumes and shipments for the expanded use alternative from the Nevada Test Site EIS (DOE 1996f, pages 5-110 to 5-112), DOE expects the traffic through the intermodal transfer station to be less than 3 trains per day and about 14 trucks per day (7 outbound from the station and 7 returning from the Nevada Test Site). Intermodal transfer operations would occur only during daytime working hours, with containers dropped off during the night transported to the Nevada Test Site the following morning. A staff of three would be adequate to conduct operations at the station. Trucks would be inspected and decontaminated, as necessary, at the Nevada Test Site before returning to the station (DOE 1998m, pages 2-1 to 2-10 unless otherwise noted).

A high-end estimate for the planned trucking operation to support the low-level radioactive waste intermodal transfer station indicates a terminal on about 0.04 to 0.06 square kilometer (10 to 15 acres), a maintenance building 21 by 23 meters (70 by 75 feet), 9 tractors and 27 trailers, and 11 employees. One proposed location would be south and just outside of Caliente. Trucks would not pass through the Town of Caliente to reach the intermodal transfer station site (DOE 1998m, page 5-4).

The projections of low-level radioactive waste shipments from current DOE-approved generators to the Nevada Test Site do not extend to 2010 when shipments of spent nuclear fuel and high-level radioactive waste would begin to the proposed Yucca Mountain Repository. However, because it is reasonable to assume that low-level radioactive waste shipments to the Nevada Test Site could continue and occur coincidentally with shipments to the Yucca Mountain Repository, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of these two intermodal transfer stations as well as a privately owned intermodal transfer station described in the following section.

Proposed Timbisha Shoshone Reservation

The Secretary of the Interior has issued a draft report to Congress (Timbisha Shoshone and DOI 1999, all) describing a plan to establish a discontiguous reservation for people of the Timbisha Shoshone Tribe in portions of the Mojave Desert in eastern California and southwestern Nevada. The plan recommends a reservation that includes land at Furnace Creek in Death Valley National Park, four separated nearby parcels of Federally held land, two parcels of lands formerly allotted to Native Americans in the Saline Valley, California, and private lands near Lida, Nevada. The plan also proposes creating cooperative management and tribal use opportunities on other portions of the Tribe's ancestral homelands. Congress would have to pass legislation to create the reservation as proposed. The National Park Service of the U.S. Department of the Interior has issued a Notice of Scoping for environmental analysis on the proposal (64 *FR* 19193, April 19, 1999).

One of the parcels of land proposed for inclusion in the Timbisha reservation is near Scotty's Junction along U.S. 95 in Nevada, which is within 80 kilometers (50 miles) of the Yucca mountain site. The Carlin and Caliente rail corridor implementing alternatives follow a common course in this area and would overlap a portion of the parcel. Similarly, the Caliente heavy-haul implementing alternative, which would use U.S. 95, would pass through one part of the parcel and along the edge of another part.

The creation of a reservation is uncertain. The timing and final form of any reservation are speculative. There is insufficient information to assess quantitatively the potential for reservation activities to affect the environment. The report (Timbisha Shoshone and DOI 1999, all) contemplates a low overall level of activity for the reservation, which would tend to minimize the potential for impacts to the environment. The report does not describe specific activities proposed for the parcel near Scotty's Junction.

Because of the contemplated low level of use, the cumulative impacts probably would be very low. For example, the reservation proposal indicates that careful planning would occur to minimize water consumption, identifies no industrial or large-scale construction activities, and indicates that traffic patterns would not increase appreciably from the creation of the reservation. Therefore, cumulative

impacts from the potential creation of this reservation do not appear to be large. Because the overall potential for cumulative impacts appears to be extremely low, the creation of a reservation would be unlikely to cause disproportionately high and adverse impacts to minority and low-income populations. If a reservation is created, DOE would work cooperatively with the Timbisha Shoshone Tribe and the government agencies directly concerned with reservation activities to minimize potential effects of transportation associated with a monitored geologic repository. The Final Yucca Mountain Repository EIS will assess information that becomes available on this project for additional impacts.

8.1.2.3 Non-Federal and Private Actions

The following paragraphs describe reasonably foreseeable future actions of non-Federal and private agencies or individuals that could result in cumulative impacts. This EIS considers the Cortez Pipeline Gold Deposit projects described below to be private actions even though they require the approval of the Bureau of Land Management.

Cortez Pipeline Gold Deposit Projects

An existing project, and two potential projects—the existing Cortez Gold Mine Pipeline Project, the proposed Pipeline Infiltration Project, and a possible Pipeline Southeast Expansion Project are near the Carlin rail corridor of the Nevada transportation implementing rail alternative (see Chapter 2, Section 2.1.3.3). Cortez Gold Mine, Inc., operates the Pipeline Project mine and processing facility and plans to operate it through 2004. The environmental impacts of the existing mining operation are discussed in the *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement* (BLM 1996, all). The proposed Pipeline Infiltration Project would expand the Pipeline Project area to add additional land for the construction and operation of infiltration ponds to support the existing mine (BLM 1999b, all). Cortez Gold Mines is studying a Pipeline Southeast Expansion Project (BLM 1996, page 5-7) that would expand mining operations southeast of the existing gold mine and would extend the life of the existing processing facility. Based on an analysis of the general area potentially affected by the Cortez Gold Mine projects, there could be cumulative land-use and ownership impacts with the Carlin branch rail line (see Figure 8-2).

Apex Bulk Commodities Intermodal Transfer Station

Apex Bulk Commodities is negotiating with BHP Copper of Ely, Nevada, to build an intermodal transfer station at Caliente near the potential intermodal transfer station site for shipping spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository. Apex anticipates one diesel truck per hour carrying 40 tons of copper concentrate, 24 hours per day, for 15 years. An improved access road and about 4,200 meters (14,000 feet) of new rail would be constructed. The transfer facility would be housed in a building 90 by 30 meters (300 by 100 feet) designed to retain dust, water, and spills generated during the transfer process. Air emission particulates would be collected in two baghouses. Apex would also need a truck maintenance facility, which would be in a building 30 by 18 meters (100 by 60 feet). An above-ground storage tank for about 45,000 liters (12,000 gallons) of diesel fuel is also planned. Apex estimates 25 new jobs for Caliente and an annual payroll of $800,000 (DOE 1998m, page 5-5).

Although a start date for Apex copper concentration intermodal transfer station and truck transportation operations is unknown, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of that station, assuming these activities would coincide with impacts from the Nevada Test Site low-level radioactive waste intermodal transfer station and the intermodal transfer station for shipments to the proposed Yucca Mountain Repository.

Shared Use of a DOE Branch Rail Line

If DOE built a branch rail line to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository, it could share the use of this line with others. A branch rail line in the Carlin corridor could provide transportation service options for mine operators in the central mountain valleys of Nevada and could provide freight service options for southwestern Nevada communities such as Tonopah, Beatty, Goldfield, and Pahrump. A branch rail line in the Caliente corridor could serve those communities plus Warm Springs, along with mine operators in the interior of Nevada. A Caliente-Chalk Mountain branch line could provide rail service to Nevada mines in the interior. A branch rail line in the Valley Modified or Jean corridors would provide freight service access to farms, industries, and businesses in the Amargosa Valley and Pahrump communities. A Valley Modified branch line would also provide rail service to the Indian Springs community. Any of the potential branch rail lines to the Yucca Mountain site (see Chapter 6, Figure 6-10) would provide rail access to the Nevada Test Site. The shared use of a branch rail line would have positive economic benefits, but could produce cumulative impacts due to increased operations and traffic.

8.2 Cumulative Short-Term Impacts in the Proposed Yucca Mountain Repository Region

This section describes short-term cumulative impacts during the construction, operation and monitoring, and closure of the repository in the regions of influence for the resources the repository could affect. DOE has organized the analysis of cumulative impacts by resource area. As necessary, the discussion of each resource area includes cumulative impacts from Inventory Module 1 or 2; from other Federal, non-Federal, and private actions; and from the combination of Inventory Modules 1 and 2 and other Federal, non-Federal, and private actions. Table 8-5 summarizes these impacts. The impacts listed for the Proposed Action in Table 8-5 include the combined effects of the potential repository and transportation activities.

There would be essentially no difference in the design and operation of the repository for Inventory Modules 1 and 2. As described in Appendix A, the radioactive inventory for Greater-Than-Class-C waste and for Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. The subsurface emplacement of the material in Inventory Module 2, in comparison with the inventory for Module 1, would not greatly increase radiological impacts to workers or the public (TRW 1999b, page 6-44). For the surface facilities, the number of workers and the radiological exposure levels would be the same for Inventory Modules 1 and 2 (TRW 1999a, Tables 6-1, 6-2, 6-4, and 6-5). Therefore, DOE did not perform separate analyses for Modules 1 and 2 to estimate the short-term impacts. This section identifies the short-term impacts as being for Modules 1 and 2, indicating that the impacts for the two modules would not differ greatly.

DOE performed quantitative calculations for long-term impacts for both modules (see Section 8.3.1). The conclusion from these quantitative estimates was that the long-term impacts for Modules 1 and 2 would not differ greatly.

8.2.1 LAND USE AND OWNERSHIP

The ownership, management, and use of the analyzed land withdrawal area described in Chapter 4, Section 4.1.1 for the Proposed Action would not change for Inventory Module 1 or 2. The amount of land required for surface facilities would increase somewhat for Module 1 or 2 because of the larger storage area for excavated rock and an additional ventilation shaft for the intermediate thermal load scenario (see Table 8-4). This would have no substantial cumulative land-use or ownership impact.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 1 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Land use and ownership	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. About 3.5 square kilometers (870 acres) of withdrawn land would be disturbed. As much as 20 square kilometers (4,900 acres) of land would be disturbed along transportation routes in Nevada, a portion of which would be in the Yucca Mountain region and could include the need for rights-of-way agreements or withdrawals.	Land withdrawal impacts would be the same as those for the Proposed Action. As much as 1 square kilometer (250 acres) of additional land would be disturbed, for a total of as much as 4.5 square kilometers (1,100 acres). Land use and ownership impacts from transportation would be the same as for the Proposed Action.	No other actions were identified with potential cumulative land-use and ownership impacts in the region of influence of repository construction, operation and monitoring, and closure. An intermodal transfer station could be constructed for shipping low-level radioactive waste within the Yucca Mountain region.	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. As much as 4.5 square kilometers (1,100 acres) of withdrawn land would be disturbed. As much as 20 square kilometers (4,900 acres) of land would be disturbed along transportation routes in Nevada, a portion of which would be in the Yucca Mountain region and could include the need for rights-of-way agreements or withdrawals.
Air Quality				
Nonradiological	Criteria pollutant [nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}, $PM_{2.5}$)] and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 5 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 5 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	**Nevada Test Site:** Baseline monitoring shows that criteria pollutants at the Nevada Test Site and in the proposed repository region are well below National Ambient Air Quality Standards and would result in very small cumulative nonradiological air quality impacts. Emissions associated with the transportation of waste, people, and materials for Nevada Test Site activities in the repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be small fractions of applicable regulatory limits (generally less than 10 percent). Emissions associated with transportation in the repository region would be low.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 2 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Air Quality (continued)				
Radiological	The maximally exposed individual in the public would receive an estimated annual radiation dose of 1.5 millirem or less (see Tables 8-9, 8-10, and 8-11), primarily from naturally occurring radon.	The maximally exposed individual in the public would receive an estimated annual dose of 2.4 millirem or less, primarily from naturally occurring radon.	**Nevada Test Site:** Activity would continue to contribute extremely small increments to the risk to the general population and should not increase injury or mortality rates. As an example, the maximally exposed individual in the public would receive an estimated annual radiation dose of 0.09 millirem from past, present and reasonably foreseeable future activities.	The maximally exposed individual in the public would receive an annual radiation dose of 2.5 millirem or less, which is well below the 40 CFR 61 limit of 10 millirem[b] from radioactive material releases from the repository and the Nevada Test Site.
Hydrology				
Surface water	About 3.5 square kilometers (870 acres) of land would be disturbed and resulting impacts would likely be small and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.	Would be similar to impacts from the Proposed Action with an increase of as much as 1 square kilometer (250 acres) in surface disturbance for a total of as much as 4.5 square kilometers (1,100 acres). Impacts from construction and use of transportation capabilities (heavy-haul and rail) would be small. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative surface-water impacts within the region of influence of repository construction, operation and monitoring, and closure. Transportation impacts would be small.	As much as 4.5 square kilometers (1,100 acres) of land would be disturbed and resulting impacts would likely be minor and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 3 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Hydrology (continued)				
Groundwater	Annual water demand (well below Nevada State Engineer's ruling on perennial yield) would be between 250 and 480 acre-feet (during emplacement) below the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). Water use for the construction of a rail line could be as much as 710 acre-feet from multiple wells and hydrographic areas over 2.5 years.	Anticipated annual water demand (below Nevada State Engineer's ruling on perennial yield) would be similar to that of the Proposed Action, but the highest demand, which would occur when emplacement and development activities occurred together, would extend for an additional 14 years. Water use for transportation would be the same as that for the Proposed Action.	**Nevada Test Site:** Anticipated annual water demand from Nevada Test Site activities would be about 280 acre-feet, which is less than the estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet).	Combining the highest annual water demand of the repository of 480 acre-feet (during emplacement and development activities for the low thermal load scenario) with annual water withdrawals from the Nevada Test Site of 280 acre-feet would result in a total of 760 acre-feet, which would exceed the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet), but would not approach the highest estimate of perennial yield, which is between 880 and 4,000 acre-feet. There is a potential for drawdown of the nearby aquifer from water withdrawal. The combined peak annual water use of a repository under an intermediate or high thermal load scenario with Nevada Test Site annual water use would result in a maximum peak cumulative use of about 530 acre-feet per year, which is below the perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). In addition, up to 710 acre-feet of water would be used to construct a rail line in Nevada.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 4 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Biological resources and soils	About 3.5 square kilometers (870 acres) of soil, habitat, and vegetation would be disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada. Impacts to the desert tortoise probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.	Inclusive of the Proposed Action, a total of as much as 4.5 square kilometers (1,100 acres) of soil, habitat, and vegetation would be disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would be the same as those under the Proposed Action. Additional wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative biological resource or soil impacts within the region of influence of repository construction, operation and monitoring, and closure.	As much as 4.5 square kilometers (1,100 acres) of soil, habitat, and vegetation would be disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Impacts to potential jurisdictional wetlands would be very small and minimized. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada, a portion of which would be within the Yucca Mountain vicinity. Impacts to the desert tortoise and wetlands probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 5 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Cultural resources	Repository development would disturb about 3.5 square kilometers (870 acres). Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations. In addition, as much as 20 square kilometers (4,900 acres) would be disturbed along transportation routes in Nevada.	Land disturbance for repository development would increase to a total of as much as 4.5 square kilometers (1,100 acres). Transportation impacts would be the same as those under the Proposed Action. Direct and indirect impacts and mitigations would be similar to the Proposed Action.	No other actions were identified with potential cumulative cultural resource impacts within the region of influence of repository construction, operation and monitoring, and closure. Native Americans view all impacts to be adverse and immune to mitigation.	Repository development would disturb as much as 4.5 square kilometers (1,100 acres). As much as 20 square kilometers (4,900 acres) would be disturbed if a rail line was constructed in Nevada. Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations.
	Native Americans view all impacts to be adverse and immune to mitigation.	Native Americans view all impacts to be adverse and immune to mitigation.		Native Americans view all impacts to be adverse and immune to mitigation.
Socioeconomics	Estimated peak direct employment of 1,800 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment. Employment increases would range from less than 1 percent to 5.7 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county.	Estimated peak employment would be the same as for the Proposed Action, but would be extended by the longer time (14 years) for emplacement and development activities. Impacts to Lincoln County would be the same as for the Proposed Action.	**Nevada Test Site:** Estimated total of approximately 4,550 direct jobs by 2005 would occur prior to construction of the repository and small cumulative impacts would be expected.	Estimated peak employment increase of about 6,350 occurring in 2005-2006 would result in less than a 4- to 9-percent increase in direct and indirect regional employment (with as much as a 5.7-percent change if intermodal transfer station or rail line were located in Lincoln County, Nevada).
Occupational and public health and safety				
Industrial hazards (nonradiological)	1 to 2 fatalities during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 11 and 16 fatalities from commuting, and transportation of material.	3 or less fatalities during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 11 and 16 fatalities from commuting, and transportation of material.	No other actions were identified with potential cumulative industrial hazard impacts.	13 to 19 fatalities during construction, operation and monitoring, and closure (including transportation). Exposures well below regulatory limits.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 6 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Occupational and public health and safety (continued)				
Radiological health impacts				
Workers	3 to 4 latent cancer fatalities from repository construction, operation and monitoring, and closure. Up to 3 or up to 11 latent cancer fatalities to workers from shipping material by rail and truck, respectively.	3 to 6 latent cancer fatalities from repository construction, operation and monitoring, and closure. Impacts from transportation would be similar to those from the Proposed Action.	No other actions were identified with potential cumulative radiological health impacts to repository workers.	About 6 to 17 latent cancer fatalities from repository construction, operation and monitoring, and closure (including transportation)
Public	Estimated doses would result in less than 1 latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Up to 3 or up to 18 latent cancer fatalities would result from shipping material by rail and truck, respectively.	Estimated doses would result in less than one latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Impacts from transportation would be similar to those from the Proposed Action.	**Nevada Test Site:** Estimated doses and associated health effects from the Nevada Test Site would be about 0.0055 latent cancer fatalities over 10 years.	About 3 to 18 latent cancer fatalities from repository construction, operation and monitoring, and closure (including transportation); and Nevada Test Site activities.
Accidents	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenarios. Between 5 and 31 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has 1.9 chances in 10 million of occurring.	The accident risk (probability of occurrence times consequence) is essentially the same as that for the Proposed Action. Impacts of a maximum reasonably foreseeable transportation accident scenario would be the same as those for the Proposed Action.	No other actions were identified with potential cumulative accident risk impacts.	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenario. Between 5 and 31 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has a 1.9 in 10 million potential of occurring.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 7 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Noise	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain region.	Same as the Proposed Action.	No other actions were identified with potential cumulative noise impacts within the region of influence of repository construction, operation and monitoring, and closure.	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain.
Aesthetics	Low. Additional structures at the repository and rail line if rail was used in Nevada. Possible conflict with visual resource management goals for Jean rail corridor.	Same as the Proposed Action.	No other actions were identified with potential cumulative aesthetic impacts within the region of influence of repository construction, operation and monitoring, and closure.	Low. Additional structures at Yucca Mountain and potential rail line in rural areas in Nevada. Possible conflict with visual resource management goals for Jean rail corridor.
Utilities, energy, materials, and site services	Peak electrical power demand would require an upgrade to the electric transmission and distribution system. No adverse impacts on energy and material supplies or to site services would be expected, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	Peak electrical power demand would require upgrade to the electric transmission and distribution system. Although requirements for electricity, fossil fuels, concrete, steel, and copper would increase, no adverse impacts to energy and material supplies or to site services would be expected, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	No other actions were identified with potential substantial cumulative utilities, energy, materials, and site services impacts within the region of influence of repository construction, operation and monitoring, and closure.	Peak electrical power demand would require upgrade to the electric transmission and distribution system. No adverse impacts on energy and material supplies or to site services would be expected, including materials needed for transportation capabilities in the Yucca Mountain vicinity.
Waste management	Disposal of repository-generated low-level waste would represent less than 3 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.	Disposal of repository-generated low-level waste would represent less than 6 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, the larger quantity of this waste would require even further landfill expansion at the Nevada Test Site.	**Nevada Test Site:** The total low-level radioactive waste disposal capacity of the Nevada Test Site is sufficient and would not be exceeded by the combined actions of repository development and selection of the Nevada Test Site as a regional disposal site for DOE-complex-wide low-level radioactive and mixed wastes.	The Nevada Test Site has sufficient capacity for low-level radioactive waste from all reasonably foreseeable future actions. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 8 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on free access to the proposed site.	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on free access to the proposed site.	No other actions were identified with potential cumulative impacts within the region of influence of repository construction, operation and monitoring, and closure that would create environmental justice concerns. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on free access to the proposed site.	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on free access to the proposed site.

a. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the analysis considered cumulative impacts from Inventory Module 2 to be the same as those from Inventory Module 1.

b. The 40 CFR Part 61 limit of 10 millirem per year is used as a point of reference even though this limit does not apply to releases of radon that would be the predominant contributor to the dose from the proposed Yucca Mountain Repository. The 10 millirem per year dose limit was established by EPA for a member of the public from emissions to the air from manmade sources.

c. dBA = A-weighted decibels, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

8.2.2 AIR QUALITY

8.2.2.1 Inventory Module 1 or 2 Impacts

This section addresses potential nonradiological and radiological cumulative impacts to air quality from emplacement in a repository at Yucca Mountain of the additional quantities of spent nuclear fuel and high-level radioactive waste above those evaluated for the Proposed Action, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (that is, Inventory Modules 1 and 2). It compares potential nonradiological and radiological cumulative impacts to applicable regulatory limits, including the new U.S. Environmental Protection Agency National Ambient Air Quality Standard for particulate matter with a diameter of less than 2.5 micrometers. A Federal appeals court recently struck down these new standards (American Trucking v. EPA 1999, all). The EIS use these standards, among other standards that were not at issue in that case, in analyzing air quality impacts. The Environmental Protection Agency has announced that it will appeal the Court's decision. Sources of nonradiological air pollutants at the proposed repository could include fugitive dust emissions from land disturbances, excavated rock handling, and concrete batch plant operations and emissions from fossil fuel consumption.

8.2.2.1.1 *Nonradiological Air Quality*

The construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository for Inventory Module 1 or 2 would result in increased releases of criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter) and cristobalite as described in the following sections. The types of activities producing these releases would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.2).

Construction. The repository construction phase for Inventory Module 1 or 2 (2005 to 2010) would produce the higher air concentrations of criteria pollutants and cristobalite listed in Table 8-6, but these concentrations would still be small fractions of the applicable regulatory limits.

Operation and Monitoring. Table 8-7 lists estimated air quality impacts from criteria pollutants and cristobalite for Inventory Module 1 or 2. The concentrations in this table are for the period of continuing subsurface development and emplacement activities. During the subsequent monitoring and maintenance activities these concentrations would decrease considerably. While somewhat higher than those produced under the Proposed Action, all concentrations would still be small fractions of the applicable regulatory limits for Module 1 or 2. Because the development of the emplacement drifts for Module 1 or 2 would take an additional 14 years (see Table 8-3), these releases of criteria pollutants would occur over a longer period than those from the Proposed Action. In general, the values in Table 8-7 for operation and monitoring are smaller than the values in Table 8-6 for construction because there would be more land surface disturbance during construction.

Closure. Continuing the closure of the repository for either Inventory Module 1 or 2 would produce concentrations of criteria pollutants and cristobalite higher than those estimated for the Proposed Action, but they would still be small fractions of the applicable regulatory limits (see Table 8-8). With Inventory Module 1 or 2, the amount of backfill required to close the ramps, main tunnels, and ventilation shafts would be larger than that for the Proposed Action, and the size of the excavated rock pile to reclaim would be larger. In addition, the duration of the closure period for Inventory Module 1 or 2 would increase over that of the Proposed Action from 6 to 13 years, 6 to 17 years, and 15 to 27 years for the high, intermediate, and low thermal load scenarios, respectively.

Table 8-6. Estimated construction phase (2005 to 2010) criteria pollutant and cristobalite concentrations at the public maximally exposed individual location (micrograms per cubic meter).

Pollutant	Averaging time	Regulatory limit[a]	Maximum concentration[b,c,d] High	Intermediate	Low	Percent of regulatory limit[d] High	Intermediate	Low
			Proposed Action					
Nitrogen dioxide[e]	Annual	100	0.36	0.36	0.39	0.36	0.36	0.39
Sulfur dioxide[e]	Annual	80	0.088	0.088	0.091	0.11	0.11	0.12
	24-hour	365	1.0	1.0	1.0	0.28	0.28	0.29
	3-hour	1,300	6.3	6.3	6.5	0.49	0.49	0.50
Carbon monoxide[e,f]	8-hour	10,000	3.8	3.8	4.1	0.037	0.037	0.040
	1-hour	40,000	23	23	25	0.058	0.058	0.062
PM_{10} ($PM_{2.5}$)[e,f]	Annual	50 (15)	0.66	0.70	0.65	1.3	1.4	1.3
	24-hour	150 (65)	6.1	6.4	6.0	4.0	4.3	4.0
Cristobalite	Annual[g]	10	0.021	0.026	0.011	0.21	0.26	0.11
			Inventory Module 1 or 2					
Nitrogen dioxide[e]	Annual	100	0.70	0.70	0.70	0.71	0.71	0.71
Sulfur dioxide[e]	Annual	80	0.12	0.12	0.12	0.16	0.16	0.16
	24-hour	365	1.3	1.3	1.3	0.35	0.35	0.35
	3-hour	1,300	8.2	8.2	8.2	0.63	0.63	0.63
Carbon monoxide[e]	8-hour	10,000	6.6	6.6	6.6	0.065	0.065	0.065
	1-hour	40,000	39	39	39	0.099	0.099	0.099
PM_{10} ($PM_{2.5}$)[e,f]	Annual	50 (15)	0.73	0.77	0.83	1.5	1.5	1.7
	24-hour	150 (65)	6.6	6.9	7.2	4.4	4.6	4.8
Cristobalite	Annual[g]	10	0.025	0.025	0.011	0.25	0.25	0.11

a. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
b. Sum of highest concentrations at the accessible land withdrawal boundary, regardless of direction.
c. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.4.
d. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
e. These values would increase by a small percentage should a Cask Maintenance Facility be collocated at the proposed repository.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

8.2.2.1.2 *Radiological Air Quality*

Inventory Module 1 or 2 would require more subsurface excavation and a longer closure phase leading to increased radon releases compared to the Proposed Action. The increased quantity of spent nuclear fuel that repository facilities would receive and package would also result in additional releases of krypton-85 from failed spent nuclear fuel cladding but, as for the Proposed Action, naturally occurring radon-222 and its radioactive decay products would still be the dominant dose contributors.

The following paragraphs discuss the estimated radiological air quality impacts in terms of the potential radiation dose to members of the public and workers for the construction, operation and monitoring, and closure phases of Inventory Module 1 or 2. For these estimates, workers exposed through the air pathway would be noninvolved workers.

Construction. Table 8-9 lists estimated doses to members of the public and workers for the construction phase. These values resulting from radon releases during the 5-year construction phase would be similar to those for the Proposed Action because the subsurface volume excavated would be about the same.

Operation and Monitoring. The doses from krypton-85 from receipt and packaging activities during the operation and monitoring phase would be very low and would be about one one-millionth (0.000001) or less of the dose from naturally occurring radon-222 and its radioactive decay products, as discussed

Table 8-7. Estimated operation and monitoring phase (2010 to 2110) criteria pollutant and cristobalite concentrations at the public maximally exposed individual location (micrograms per cubic meter).

Pollutant	Averaging time	Regulatory limit[a]	Maximum concentration[b,c,d] High	Intermediate	Low	Percent of regulatory limit[d] High	Intermediate	Low
			Proposed Action[e]					
Nitrogen dioxide	Annual	100	0.45	0.45	0.82	0.46	0.46	0.83
Sulfur dioxide	Annual	80	0.14	0.14	0.16	0.18	0.18	0.23
	24-hour	365	1.8	1.8	2.1	0.50	0.50	0.57
	3-hour	1,300	11	11	13	0.87	0.87	1.0
Carbon monoxide	8-hour	10,000	4.2	4.2	7.3	0.041	0.041	0.072
	1-hour	40,000	28	28	46	0.070	0.070	0.11
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.22	0.22	0.27	0.43	0.44	0.54
	24-hour	150 (65)	3.0	3.1	3.4	2.0	2.1	2.3
Cristobalite	Annual[g]	10	0.0097	0.012	0.015	0.097	0.12	0.15
			Inventory Module 1 or 2[e]					
Nitrogen dioxide	Annual	100	0.49	0.56	0.82	0.49	0.56	0.82
Sulfur dioxide	Annual	80	0.15	0.15	0.18	0.19	0.20	0.23
	24-hour	365	1.8	1.9	2.1	0.51	0.52	0.57
	3-hour	1,300	12	12	13	0.89	0.92	1.0
Carbon monoxide	8-hour	10,000	4.5	5.2	7.2	0.044	0.051	0.070
	1-hour	40,000	30	33	45	0.074	0.084	0.11
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.23	0.24	0.27	0.46	0.48	0.55
	24-hour	150 (65)	3.2	3.2	3.5	2.1	2.1	2.3
Cristobalite	Annual[g]	10	0.013	0.014	0.017	0.13	0.14	0.17

a. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
b. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
c. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.5.
d. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
e. These values would increase by less than 4 percent if a Cask Maintenance Facility was located at the proposed repository.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

below. The annual dose from krypton-85 would be the same as that for the Proposed Action, but would occur for 38 rather than 24 years.

Table 8-10 lists doses to individuals and populations for the operation and monitoring phase. In all cases, naturally occurring radon-222 would be the dominant contributor to the doses, which would increase based on the additional excavation required for Inventory Module 1 or 2. Average annual doses would be higher to members of the public and higher to noninvolved workers during the 38 years of development and emplacement activities when the South Portal would be open and used for exhaust ventilation. The analysis estimated collective doses for public and worker populations for the 100 years of the operation and monitoring phase, including the 38 years of development and emplacement activities and 62 years of monitoring and maintenance activities. The dose to the maximally exposed member of the public is for 38 years of operations and 32 years of monitoring (that is, a 70-year lifetime). The dose to the maximally exposed noninvolved worker is for 50 years at the South Portal during development, emplacement, and monitoring activities.

Closure. Table 8-11 lists estimated doses to populations and maximally exposed individuals during the closure phase. Radiation doses would increase over those for the Proposed Action not only because of the larger excavated volume but also the longer time required for closure (13 to 27 years) in comparison to 6 to 15 years. The annual radon emissions and doses during closure would be the same as those for

Table 8-8. Estimated closure phase[a] criteria pollutant and cristobalite concentrations at the public maximally exposed individual location (micrograms per cubic meter).

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c,d,e] High	Maximum concentration[c,d,e] Intermediate	Maximum concentration[c,d,e] Low	Percent of regulatory limit[d] High	Percent of regulatory limit[d] Intermediate	Percent of regulatory limit[d] Low
			Proposed Action					
Nitrogen dioxide[f]	Annual	100	0.080	0.13	0.12	0.080	0.13	0.12
Sulfur dioxide[f]	Annual	80	0.0076	0.013	0.011	0.0097	0.016	0.014
	24-hour	365	0.057	0.093	0.082	0.016	0.025	0.022
	3-hour	1,300	0.45	0.74	0.66	0.035	0.057	0.050
Carbon monoxide[f]	8-hour	10,000	0.67	1.1	0.98	0.0065	0.011	0.0095
	1-hour	40,000	4.1	6.6	5.9	0.010	0.017	0.015
PM_{10} ($PM_{2.5}$)[f,g]	Annual	50 (15)	0.52	0.56	0.53	1.0	1.1	1.1
	24-hour	150 (65)	6.5	6.8	6.6	4.3	4.5	4.4
Cristobalite	Annual[h]	10	0.010	0.014	0.0053	0.10	0.14	0.053
			Inventory Module 1 or 2					
Nitrogen dioxide[f]	Annual	100	0.11	0.12	0.14	0.11	0.12	0.14
Sulfur dioxide[f]	Annual	80	0.011	0.011	0.013	0.014	0.014	0.016
	24-hour	365	0.079	0.081	0.093	0.021	0.022	0.026
	3-hour	1,300	0.63	0.65	0.75	0.048	0.050	0.057
Carbon monoxide[f]	8-hour	10,000	0.94	0.97	1.1	0.0092	0.0094	0.011
	1-hour	40,000	5.7	5.8	6.7	0.014	0.015	0.017
PM_{10} ($PM_{2.5}$)[f,g]	Annual	50 (15)	0.55	0.60	0.68	1.1	1.2	1.4
	24-hour	150 (65)	6.8	7.1	7.6	4.5	4.7	5.1
Cristobalite	Annual[h]	10	0.013	0.013	0.0056	0.13	0.13	0.056

a. Duration of closure phase would be 6 years for high and intermediate thermal load scenarios and 15 years for low thermal load scenario.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.6.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. These values would increase by a small percentage should a cask maintenance facility be co-located at the proposed repository.
g. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
h. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

monitoring and maintenance activities because the release points would be the same and because the quantities released would depend on the excavated volume. No reduction in radon releases from backfilling the main tunnels is assumed. The collective dose to the repository worker population would vary with the packaging scenario, because labor for the closure of the surface facilities would differ among these scenarios.

Summary. Based on the analysis of radiological air quality impacts from repository construction, operation and monitoring, and closure for Inventory Module 1 or 2, the highest estimated average annual dose to the maximally exposed individual member of the public would be 2.5 millirem for the low thermal load scenario during development and emplacement activities in the operation and monitoring phase. As a point of reference, this dose would be 25 percent of the 10-millirem-per-year regulatory limit in 40 CFR Part 61, even though this limit does not apply to releases of radon that are the predominant contributor to this dose. The radiation dose is 0.7 percent of the annual 340-millirem natural background dose to individuals in Amargosa Valley. Section 8.2.7 discusses human health impacts to the public that

Table 8-9. Estimated construction phase (2005 to 2010) radon-222 radiation doses to maximally exposed individuals and populations.[a,b]

Dose	Thermal load: High, Total	High, Annual average[c]	Intermediate, Total	Intermediate, Annual average	Low, Total	Low, Annual average
	Proposed Action					
Public						
MEI[d] (millirem)	2.1	0.43	2.5	0.49	2.5	0.49
Population[e] (person-rem)	11	2.3	13	2.6	13	2.6
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[f] (millirem)	23	4.7	27	5.4	27	5.4
Worker population[g] (person-rem)						
Uncanistered	9.0	1.8	10	2.0	10	2.0
Noninvolved Nevada Test Site workers						
Worker population[h] (person-rem)	0.012	0.0025	0.014	0.0028	0.014	0.0028
	Inventory Module 1 or 2					
Public						
MEI[d] (millirem)	2.4	0.48	2.4	0.48	2.4	0.48
Population[e] (person-rem)	13	2.6	13	2.6	13	2.6
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[f] (millirem)	26	5.2	26	5.2	26	5.2
Worker population[g] (person-rem)	10	2.0	10	2.0	10	2.0
Noninvolved Nevada Test Site workers						
Worker population[h] (person-rem)	0.014	0.0027	0.014	0.0027	0.014	0.0027

a. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.2.
b. Totals might differ from sums due to rounding.
c. Annual average doses reflect the increasing repository volume and resulting increasing radon-222 releases during subsurface construction.
d. MEI is the maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository.
e. The population includes about 28,000 individuals within about 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Operations Area.
g. Values vary slightly (less than 2 percent) by packaging scenario due to differences in the number of surface workers.
h. DOE workers at the Nevada Test Site [about 6,600 workers (DOE 1996f, Volume I, page A-69) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

could result from radiation exposures during construction, operation and monitoring, and closure for Inventory Module 1 or 2.

8.2.2.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

This section addresses potential nonradiological and radiological cumulative impacts to air quality from activities at the repository for the Proposed Action or Inventory Module 1 or 2 and other Federal, non-Federal, and private actions that would coincide with repository operations and potentially affect the air quality within the geographic boundaries of repository air quality impacts.

8.2.2.2.1 *Nonradiological Air Quality*

Construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository would have very small impacts on regional air quality for the Proposed Action or for Inventory Module 1 or 2. Annual average concentrations of criteria pollutants at the land withdrawal boundary would be 1 percent or less of applicable regulatory limits except for PM_{10}, which the analysis estimated would be as much as 5 percent

Table 8-10. Estimated operation and monitoring phase (2010 to 2110) total radiation doses to maximally exposed individuals and populations.[a,b]

	Thermal load					
	High		Intermediate		Low	
Dose	Total	Annual average[c]	Total	Annual average	Total	Annual average
	Proposed Action					
Public						
MEI[d] (millirem)	38	0.55	45	0.65	100	1.5
Population[e] (person-rem)	260	2.6	310	3.1	710	7.1
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[f] (millirem)	82	3.4	82	3.4	82	3.4
Worker population (person-rem)						
Uncanistered	64	0.64	76	0.74	140	1.4
Disposable canister	62	0.62	74	0.73	130	1.3
Dual-purpose canister	62	0.62	74	0.73	130	1.3
Nevada Test Site noninvolved workers						
Worker population[g] (person-rem)	0.39	0.0039	0.46	0.0046	1.1	0.011
	Inventory Module 1 or 2					
Public						
MEI[h] (millirem)	68	0.97	67	0.96	170	2.4
Population[e] (person-rem)	470	4.7	460	4.6	1,200	12
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[h] (millirem)	130	3.4	130	3.4	130	3.4
Worker population[i] (person-rem)	140	1.4	140	1.4	330	3.3
Nevada Test Site noninvolved workers						
Worker population[h] (person-rem)	0.67	0.0067	0.68	0.0068	1.7	0.017

a. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.2.
b. Totals might differ from sums due to rounding.
c. Annual average doses reflect radon releases from the increasing repository volume and varying ventilation flows during subsurface development.
d. MEI is the maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository. Dose estimate is based on 24 years of operations and 46 years of monitoring for a total of 70 years.
e. The population includes about 28,000 individuals within about 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Operations Area (from radon-222 exposure) for a 50-year working lifetime including 24 years of operations activities and 26 years of monitoring activities.
g. DOE workers at the Nevada Test Site [about 6,600 workers (DOE 1996f, Volume I, page A-69) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].
h. Dose estimate is based on 38 years of operations and 12 years of monitoring for a total of 50 years.
i. Values vary slightly (less than 2 percent) by packaging scenario due to differences in the number of surface workers.

of the regulatory limit at the land withdrawal boundary. This estimate does not consider standard dust suppression activities (such as wetting), so actual concentrations probably would be much lower.

DOE has monitored particulate matter concentrations in the Yucca Mountain region since 1989; gaseous criteria pollutants were monitored from October 1991 through September 1995. Concentrations were well below applicable National Ambient Air Quality Standards (see Section 3.1.2.1). In 1990, DOE also measured ambient air quality in several Nevada Test Site areas for short-term concentrations of sulfur dioxide, carbon monoxide, and PM_{10} (DOE 1996f, Volume I, pages 4-146 and 4-148). The measurements were all lower than the applicable short-term (1-hour, 3-hour, 8-hour, and 24-hour) limits.

Table 8-11. Estimated closure phase radon-222 radiation doses to maximally exposed individuals and populations.[a,b]

	Thermal load					
	High		Intermediate		Low	
Dose	Total	Annual[c]	Total	Annual	Total	Annual
	Proposed Action					
Public						
MEI[d] (millirem)	2.6	0.43	3.1	0.5	19	1.2
Population[e] (person-rem)	13	2.1	15	2.5	93	6.2
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[f] (millirem)	0.24	0.039	0.28	0.047	1.7	0.12
Worker population[g] (person-rem)						
Uncanistered	0.041	0.0068	0.049	0.0082	0.12	0.020
Disposable canister	0.029	0.0049	0.035	0.0058	0.086	0.014
Dual-purpose canister	0.032	0.0053	0.038	0.0063	0.092	0.016
Nevada Test Site noninvolved workers						
Worker population[h] (person-rem)	0.021	0.0035	0.025	0.0042	0.16	0.010
	Inventory Module 1 or 2					
Public						
MEI[d] (millirem)	10	0.78	14	0.80	58	2.1
Population[e] (person-rem)	51	3.9	68	4.0	290	11
Noninvolved workers (surface)						
Maximally exposed noninvolved worker[f] (millirem)	0.94	0.072	1.3	0.074	1.9	0.07
Worker population[g] (person-rem)						
Uncanistered	0.073	0.012	0.075	0.012	0.15	0.026
Disposable canister	0.051	0.0086	0.053	0.0088	0.11	0.018
Dual-purpose canister	0.055	0.0093	0.057	0.0094	0.12	0.019
Nevada Test Site noninvolved workers						
Worker population[h] (person-rem)	0.085	0.0065	0.11	0.0067	0.48	0.018

a. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.2.
b. Totals might differ from sums due to rounding.
c. For purposes of analysis, annual radon-222 releases remain constant over the closure phase.
d. MEI is the maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository.
e. The population includes about 28,000 individuals within about 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Operations Area.
g. Values vary slightly by packaging scenario due to differences in the number of surface workers.
h. DOE workers at the Nevada Test Site [about 6,600 workers (DOE 1996f, Volume I, page A-69) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Pollutant concentrations related to Nevada Test Site activities would be well below ambient air quality standards and would not increase ambient pollutant concentrations above standards in Nye County (DOE 1996f, Volume I, page 4-146). Therefore, DOE expects the cumulative impacts from proposed repository and Nevada Test Site operations to be very small.

Repository activities would have no effect on air quality in the Las Vegas Valley air basin, which is a nonattainment area for carbon monoxide and PM_{10}, because the Las Vegas Valley air basin lies approximately 120 kilometers (75 miles) southeast of the proposed repository site.

8.2.2.2.2 *Radiological Air Quality*

Past activities at the Nevada Test Site are responsible for the seepage of radioactive gases from underground testing areas and slightly increased krypton-85 levels on Pahute Mesa in the northwest corner of the Nevada Test Site (see Figure 8-2). Some radioactivity on the site is attributable to the resuspension of soils contaminated from past above-ground nuclear weapons testing (DOE 1996f, Volume I, page 4-149). Current Nevada Test Site defense program activities have not resulted in detectable offsite levels of radioactivity. Estimated radiation doses to the public during 1997 were 0.089 millirem to the maximally exposed individual [a hypothetical resident of Springdale, Nevada, which is about 18 kilometers (11 miles) west of the Nevada Test Site (see Figure 8-2)] and 0.26 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources (Bechtel 1998, page 7-1). The radiation dose estimates from repository construction, operation and monitoring, and closure (see Tables 8-9, 8-10, and 8-11) would add to these estimates assuming the exposed individuals and population were the same (they are not). Conservatively adding the 1997 maximally exposed individual dose from the Nevada Test Site to the highest estimated average annual dose to the maximally exposed individual from repository operations [hypothetical individual located 20 kilometers (12 miles) south of the repository] (2.4 millirem) results in a cumulative dose of 2.5 millirem. This is about 40 percent of the 40 CFR Part 61 limit of 10 millirem and about 0.7 percent of the annual 340 millirem natural background radiation dose to individuals in Amargosa Valley. Conservatively adding the 1997 Nevada Test Site and highest estimated annual repository population dose (12 person-rem) results in a cumulative dose of 12 person-rem. No latent cancer fatalities to the population would be expected from this cumulative exposure (see Section 8.2.7).

The only other activity identified in the 80-kilometer (50-mile)-radius region of influence that could affect radiological air quality is a low-level radioactive disposal site near Beatty, Nevada, which was officially closed on January 1, 1993. The physical work of a State-approved Stabilization and Closure Plan ended in July 1994. Custodianship of the site has been transferred to the State of Nevada. Monitoring is continuing at the site to ensure that any radioactive material releases to the air continue to be low (NSHD 1999, Section on the Bureau of Health Protection Services).

8.2.3 HYDROLOGY

8.2.3.1 Surface Water

Potential impacts to surface waters from the Proposed Action would be relatively minor and limited to the immediate vicinity of land disturbances associated with the action (see Chapter 4, Section 4.1.3.2, and the floodplain/wetlands assessment in Appendix L). Surface-water impacts of primary concern would include the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage

This section addresses these impact areas in a discussion of possible increases or other changes that could occur as a result of the emplacement of Inventory Module 1 or 2. To be cumulative, other Federal, non-Federal, or private action effects would have to occur in the immediate area. No currently identified actions have affected meeting this criterion.

Introduction and Movement of Contaminants

For Inventory Module 1 or 2, there would be essentially no change in the potential for soil contamination during the construction, operation and monitoring, and closure phases. There would be no change in the

types of contaminants present nor would there be changes in operations that would make spills or releases more likely. Similarly, there would be no change in the threat of flooding to cause contaminant releases beyond that described for the Proposed Action.

Changes to Runoff or Infiltration Rates
Compared to the estimated area of land disturbed under the Proposed Action, Inventory Module 1 or 2 would require the disturbance of additional land for the corresponding thermal load scenario (see Table 8-4). A maximum of about 2.8 square kilometers (1.1 square miles) of land would be disturbed for Module 1 or 2 for the low thermal load scenario. This increase in disturbed land would still be a relatively small portion of the natural drainage areas and would make little difference in the amount of water that soaked into the ground or reached the intermittently flowing drainage channels. Disturbed areas not covered by structures would slowly return to conditions more similar to those of the surrounding undisturbed ground.

Alterations of Natural Drainage
No additional actions or land disturbances associated with Inventory Module 1 or 2 would involve a potential to alter noteworthy natural drainage channels in the area. The excavated rock pile and its increased size for Module 1 or 2 would be in an area that would obstruct a very small portion of overland drainage. Potential impacts to floodplains would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.3.4). The construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on which routes DOE selected. Appendix L contains a floodplain/wetlands assessment that describes the actions DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity.

8.2.3.2 Groundwater

8.2.3.2.1 *Inventory Module 1 or 2 Impacts*

Potential groundwater impacts would be related to the following:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

Changes to Infiltration and Aquifer Recharge. If DOE emplaced Inventory Module 1 or 2, changes related to infiltration and recharge rates would be limited to two areas: a possible increase in the size of the excavated rock pile and an extended scope for subsurface activities. The following paragraphs discuss these items.

Additional land disturbance anticipated during the operation and monitoring phase would be the continued growth of the excavated rock pile. Depending on the thermal load scenario, this could involve an additional 0.15 to 0.85 square kilometer (0.06 to 0.33 square mile) of land over that required for the

Proposed Action (see Table 8-4). Although the excavated rock pile could have different infiltration rates than undisturbed ground, it probably would not be a recharge location because of the extended depth of unconsolidated material, nor would it be likely to cause a large change in the amount of water that would otherwise reach recharge areas such as drainage channels.

Underground activities and their associated potential to contribute to the deep infiltration of water would be basically the same as those described for the Proposed Action, except emplacement drift construction would take an estimated 36 years to complete with either Inventory Module 1 or 2, compared to 22 years for the Proposed Action (see Table 8-3). As described for the Proposed Action, the quantities of water in the subsurface not removed to the surface by ventilation or pumping and thus available for infiltration would be small and primarily limited to the duration of drift development when the largest quantities of water would be used in the subsurface for dust control.

Potential for Contaminant Migration to Groundwater Zones. Neither Inventory Module 1 nor 2 would involve additional actions likely to increase the potential for contaminant releases to the environment. The only possible exception to this could be the extended period of subsurface excavation activities to accommodate the additional inventory. However, this exception would be an extension of activities with minimal potential to involve substantial contaminant releases.

Potential to Deplete Groundwater Resources. Anticipated annual water demand for Inventory Module 1 or 2 would be the same or very similar to that projected for the Proposed Action. Table 8-12 summarizes estimated annual water demands for both the Proposed Action and Inventory Module 1 or 2. The table indicates only small variations in water demand during construction, with the minor differences attributable to slight changes in the rate at which subsurface development would occur.

Projected annual water demand during emplacement and development activities of the operation and monitoring phase (as listed in Table 8-12) would be very similar under Inventory Module 1 or 2 and would actually decrease under the low thermal load scenario. However, a decrease in annual demand would be the direct result of extending the duration of drift development from 22 to 36 years. [While the total quantity of water consumed during emplacement and development activities would increase by 40 to 60 percent (depending on the thermal load) over the Proposed Action, it would be withdrawn over more years.]

Projected annual water demand during monitoring activities of the operation and monitoring phase would be the same under either the Proposed Action or Inventory Module 1 or 2. In either case, the demands listed in Table 8-12 represent the highest projected during monitoring, which would last only about 3 years during surface facility decontamination. There would be very minimal water demand during the remaining monitoring activities. The closure phase for Module 1 or 2 shows there would be a decrease in projected annual water demand in comparison to the Proposed Action. This would be due to the closure phase being longer under Module 1 or 2. That is, the annual water demand would decrease, but the total amount that would be used over the entire phase would increase.

Potential impacts to water resources under Inventory Module 1 or 2 would be very similar to those under the Proposed Action because the annual water demand would change little, and the best understanding of the groundwater resource is that it is replenished on an annual basis as gauged by the perennial yield of the groundwater basin. Under Module 1 or 2, the repository's annual water demand from the western two-thirds of the Jackass Flats basin would remain below the lowest estimated value for its perennial yield of [720,000 cubic meters (580 acre-feet)] (see Chapter 3, Table 3-11).

Table 8-12. Estimated annual water demand (acre-feet) for the Proposed Action and Inventory Module 1 or 2.[a,b]

Phase	Thermal Load		
	High	Intermediate	Low
	Proposed Action		
Construction (2005 to 2010)	150	170	170
Operation and monitoring (2010 to 2110)			
Emplacement and development activities[c]			
Uncanistered	250	260	480
Disposable canister	220	230	450
Dual-purpose canister	220	230	450
Monitoring activities (first 3 years)[d,e]			
Uncanistered	200	200	200
Disposable canister	160	160	160
Dual-purpose canister	160	160	160
Closure			
Uncanistered	80	90	90
Disposable canister	80	90	90
Dual-purpose canister	80	90	90
	Inventory Module 1 or 2		
Construction (2005 to 2010)	150	150	150
Operation and monitoring (2010 to 2110)			
Emplacement and development activities[c]			
Uncanistered	250	260	430
Disposable canister	220	230	400
Dual-purpose canister	220	230	400
Monitoring activities (first 3 years)[d,e]			
Uncanistered	200	200	200
Disposable canister	160	160	160
Dual-purpose canister	160	160	160
Closure			
Uncanistered	60	60	70
Disposable canister	60	60	70
Dual-purpose canister	60	60	70

a. Source: TRW (1999a, pages 73, 76, and 80); TRW (1999b, pages 6-3, 6-14, 6-21, 6-25, 6-26, 6-37, 6-45, 6-53, 6-61, 6-65, and 6-77).

b. To convert acre-feet to cubic meters, multiply by 1,233.49.

c. A collocated Cask Maintenance Facility would increase these values by 2 to 5 percent.

d. Values shown for monitoring activities are applicable only to the first 3 years when decontamination of surface facilities would be performed. Water demand for the 73 years that follow would be low.

e. A collocated Cask Maintenance Facility would increase these values by 5 to 7 percent.

8.2.3.2.2 *Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions*

Potential impacts to groundwater, as described in Chapter 4, Section 4.1.3.3, and in Section 8.2.3.2.1, for the Proposed Action and Inventory Module 1 or 2 would be small and limited to the immediate vicinity of land disturbances associated with the action. The exception to this would be the potential impact from water demands on groundwater resources. With this single exception, other Federal, non-Federal, or private action effects would have to occur in the same region of influence to be cumulative with those resulting from the Proposed Action or Inventory Module 1 or 2, and no currently identified actions meet this criterion.

The remainder of this discussion addresses the exception to this statement potential impacts to groundwater resources from water demand.

The discussion of impacts to groundwater resources in Chapter 4, Section 4.1.3.3, includes ongoing water demands from Area 25 of the Nevada Test Site. Area 25 is the proposed location of the primary repository surface facilities. It is also the location of wells J-12 and J-13, which would provide water for the Proposed Action and for ongoing Nevada Test Site activities in this area. The estimated water demand for these ongoing activities is 340,000 cubic meters (280 acre-feet) a year (DOE 1998n, Table 11-2, page 11-6).

As with the Proposed Action, water demand during emplacement and development activities of the operation and monitoring phase under Inventory Module 1 or 2 combined with the baseline demands from Nevada Test Site activities would exceed the lowest perennial yield estimate under the low thermal load scenario. The combined water demands under either the high or intermediate thermal load scenario, and with any of the packaging scenarios, would be below the lowest estimates of perennial yield for the western two-thirds of Jackass Flats. None of the water demand estimates would approach the high estimate of perennial yield for the entire Jackass Flats hydrographic basin, which is 4.9 million cubic meters (4,000 acre-feet) (see Chapter 3, Table 3-11). Potential impacts to groundwater resources from this combined demand would be no different than those described in Chapter 4, Section 4.1.3.3. That is, some decline in the water level would be likely near the production wells, but not extensively over the Jackass Flats basin, and general groundwater flow patterns could shift very slightly to accommodate the withdrawals. Changes in general flow patterns probably would be too small for estimation or detection.

The Nevada Test Site EIS (DOE 1996f, pages 3-18, 3-19, and 3-34) indicates that the potential construction and operation of a Solar Enterprise Zone facility would represent the only action that would cause water withdrawals on the Test Site to exceed past levels. That EIS estimates that this demand would be greater than the highest estimates of the basin's perennial yield. Therefore, cumulative impacts from the Solar Enterprise Zone facility are likely. DOE is considering several locations for the Solar Enterprise Zone facility, one of which is Area 25. If DOE built this facility in Area 25, it would obtain water from the Jackass Flats hydrologic area, and possibly from other hydrologic areas.

Cumulative demands on the Jackass Flats hydrographic area could have long-term impacts on water availability in the downgradient aquifers beneath Amargosa Desert. The groundwaters in these areas are hydraulically linked, but the exact nature and extent of that link is still a matter of study and some speculation. However, the amount of water already being withdrawn in the Amargosa Desert [averaging about 18 million cubic meters (15,000 acre-feet) of water per year from 1995 through 1997 (see Chapter 3, Table 3-10)] is much greater than the quantities being considered for withdrawal from Jackass Flats. If water pumpage from Jackass Flats were to affect water levels in Amargosa Desert, the impacts would be small in comparison to those caused by local pumping in the Amargosa Desert.

A report from the Nye County Nuclear Waste Repository Office (Buqo 1999, pages 39 to 53) provides a perspective of potential cumulative impacts with that County as the center of interest. The Nye County report evaluates impacts to all water resources potentially available in the entire county, whereas this EIS focuses principally on impacts to the Jackass Flats groundwater basin (the source of water that DOE would use for the repository) and the groundwater system that could become contaminated thousands of years in the future. Nye County reports that the potential cumulative impacts would include additive contamination as radionuclides ultimately reached the groundwater, constraints on development of groundwater due to land withdrawal, and reduction of water available for Nye County development because of use by Federal agencies (Buqo 1999, pages 49 to 51).

8.2.4 BIOLOGICAL RESOURCES

Impacts to biological resources from Inventory Module 1 or 2 would be similar to impacts that would occur as a result of the Proposed Action evaluated in Chapter 4, Section 4.1.4. Those impacts would occur primarily as a result of site clearing, placement of material in the excavated rock pile, habitat loss, and the loss of individuals of some animal species during site clearing and from vehicle traffic.

Inventory Module 1 or 2 would require disturbing biological resources in a larger area under each thermal load scenario than would be disturbed under the Proposed Action, primarily because the excavated rock pile would be larger (Table 8-13).

Table 8-13. Area of land cover types in analyzed withdrawal area disturbed by construction and the excavated rock pile (square kilometers).[a,b,c]

	Total area		Disturbed area		
Land cover	Nevada	Withdrawal area[d]	High thermal load	Intermediate thermal load	Low thermal load[e]
			Proposed Action		
Blackbrush	9,900	140	0.02	0.02	0.36
Creosote-bursage	15,000	290	0.62	0.72	1.1
Mojave mixed scrub	5,600	120	0.8	0.86	0.03
Sagebrush	67,000	16	0	0	0
Salt desert scrub	58,000	20	0	0	0
Previously disturbed[f]	NA[g]	4	0.37	0.37	0.48
Totals	**NA**	**590**	**1.82**	**1.97**	**1.98**
			Inventory Module 1 or 2		
Blackbrush	9,900	140	0.02	0.02	0.31
Creosote-bursage	15,000	290	0.72	0.87	2.0
Mojave mixed scrub	5,600	120	0.86	0.95	0.03
Sagebrush	67,000	16	0	0	0
Salt desert scrub	58,000	20	0	0	0
Previously disturbed[f]	NA	4	0.37	0.37	0.48
Totals	**NA**	**590**	**1.97**	**2.21**	**2.83**

a. Source: Facility diagrams from TRW (1999b; Figures 6.1.7-1, 6.1.7-2, 6.2.7-1, and 6.2.7-2; pages 6-42, 6-43, 6-84, and 6-85) overlain on the land cover types map (Utah State University 1996, GAP data; TRW 1998c, page 9 as adapted) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. A small area [0.016 square kilometer (4 acres)] of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
e. As described in Chapter 2, the excavated rock pile would be in a different location for a low thermal load scenario.
f. Estimate.
g. NA = not applicable.

Repository construction and the excavated rock pile to support Inventory Module 1 or 2 would disturb about 3.5 square kilometers (870 acres) of vegetation under any of the thermal load scenarios. For the low thermal load scenario, about 2 square kilometers (500 acres) of the disturbed area would result from the excavated rock pile. Disturbances would occur in areas dominated by Mojave mixed scrub and salt desert scrub land cover types. These cover types are widespread in the withdrawal area and in Nevada. Although this disturbed area is larger than that for the Proposed Action, it still would affect vegetation on less than 1 percent of the land withdrawal area.

Releases of radioactive materials would not adversely affect biological resources. Routine releases would consist of noble gases, primarily krypton-85 and radon-222. These gases would not accumulate in the environment around Yucca Mountain and would result in low doses to plants or animals.

Overall impacts to biological resources from Inventory Module 1 or 2 would be very small. Species at the repository site are generally widespread throughout the Mojave or Great Basin Deserts and repository activities would affect a very small percentage of the available habitat in the region. Changes in the regional population of any species would be undetectable and no species would be threatened with extinction. The removal of vegetation from the small area required for Module 1 or 2 or the local loss of small numbers of individuals of some species due to site clearing and vehicle traffic would not affect regional biodiversity and ecosystem function. The loss of desert tortoise habitat and small numbers of tortoises under Module 1 or 2 would have no impact on recovery efforts for this threatened species.

Activities associated with other Federal, non-Federal, and private actions in the region should not add measurable impacts to the overall impact on biological resources. However, as stated in the Nevada Test Site EIS (DOE 1996f, page 6-16), cumulative impacts to the desert tortoises would occur throughout the region, although the intensity of the impacts would vary from location to location. The largest impact to the habitat probably would occur in the Las Vegas Valley region. The Clark County Desert Conservation Plan authorizes the taking of all tortoises on 445 square kilometers (110,000 acres) of non-Federal land in the County, and on 12 square kilometers (3,000 acres) disturbed by Nevada Department of Transportation activities in Clark and adjacent counties. The plan also authorizes several recovery units designed to optimize the survival and recovery of this threatened species. Potential land disturbance activities at the Nevada Test Site under the expanded use alternative represent a small amount of available desert tortoise habitat and will not add measurably to the loss of this species (DOE 1996f, page 6-16). As discussed in Chapter 4, Section 4.1.4, repository construction activities would involve the loss of an amount of desert tortoise habitat that would be small in comparison to its range. Yucca Mountain is at the northern end of the range of this species. DOE anticipates that small numbers of tortoises would be killed inadvertently by vehicle traffic during the repository construction, operation and monitoring, and closure phases.

8.2.5 CULTURAL RESOURCES

The only identified actions that could result in cumulative cultural resource impact in the Yucca Mountain site vicinity are Inventory Module 1 or 2. The emplacement of either module would require small additional disturbances to land in areas already surveyed during site characterization activities (see Table 8-4). Because repository construction, operation and monitoring, and closure would be Federal actions, DOE would identify and evaluate cultural resources, as required by Section 106 of the National Historic Preservation Act, and would take appropriate measures to avoid or mitigate adverse impacts to such resources. As a consequence, archaeological information gathered from artifact retrieval during land disturbance would contribute additional cultural resources information to the regional data base for understanding past human occupation and use of the land. However, there would be a potential for illicit or incidental vandalism of archaeological or historic sites and artifacts as a result of increased activities in the repository area, which would be extended for Module 1 or 2 (see Table 8-3), and this could contribute to an overall loss of regional cultural resources information.

The Native American view of resource management and preservation is holistic in its definition of cultural resources, incorporating all elements of the natural and physical environment in an interrelated context (AIWS 1998, all). The Native American perspective on cultural resources is further discussed in Chapter 3, Section 3.1.6. Potential impacts resulting from the Proposed Action described in Chapter 4, Section 4.1.5, would also apply to Inventory Module 1 or 2.

8.2.6 SOCIOECONOMICS

8.2.6.1 Inventory Modules 1 and 2 Impacts

This section addresses potential impacts associated with Inventory Module 1 or 2 on socioeconomic indicators that would be above the impacts estimated for the Proposed Action (Section 4.1.6). As described in Chapter 4, Section 4.1.6, DOE established a bounding case to examine the maximum potential workforces it would need to implement thermal load scenarios and packaging scenarios and to identify the scenario combination that would have the highest employment—low thermal load with uncanistered packaging. The analysis of Inventory Modules 1 and 2 assumes the same combination. Table 8-14 summarizes the peak direct employment levels during all phases for the Proposed Action and Module 1 or 2.

Table 8-14. Estimated peak direct employment level impacts from repository phases.

Phase	Years	Peak direct employment levels[a,b]	
		Proposed Action	Module 1 or 2
Construction	2005-2010	2,400	1,600
Operation and monitoring	2010-2110		
Development and emplacement		1,800	1,800
Monitoring and maintenance		120	120
Closure	2110-varies	520	520

a. Sources: TRW (1999a, all); TRW (1999b, all).

b. Cask Maintenance Facility-related construction, operation and monitoring, and closure activities would result in an increase to peak employment of approximately 4 percent.

Construction

DOE expects the construction phase to last from 2005 until 2010. In relation to employment, the construction phase for Inventory Module 1 or 2 would require the same peak number of workers as the Proposed Action (see Table 8-14). The impacts for Module 1 or 2 would therefore be the same as those for the Proposed Action.

Operation and Monitoring

DOE expects the operation and monitoring phase to last from 2010 until 2110. Employment levels during the continuing development of the emplacement drifts and emplacement activities and during monitoring and maintenance activities would be similar to those during the Proposed Action (see Table 8-14). Although the overall duration of the operation and monitoring phase would be 100 years, the primary difference between Inventory Module 1 or 2 and the Proposed Action is the increased duration of development and emplacement activities and the reduced duration of monitoring and maintenance activities. (Under Module 1 or 2, DOE would require an additional 14 years to complete the emplacement of the waste packages. Monitoring and maintenance would still end in 2110, which would shorten the duration of these activities by 14 years).

The annualized impacts during development and emplacement activities for Inventory Module 1 or 2 would be similar to those for the Proposed Action continued an additional 14 years. Cumulative impacts would occur primarily between 2033 (the last year of Proposed Action emplacement) and 2047 (when Module 1 or 2 emplacement would end). As with the Proposed Action, direct and indirect increases in regional employment, population, personal income, Gross Regional Product, and government expenditures for Module 1 or 2 would be small. No substantial impacts would be likely during operation and monitoring for Module 1 or 2.

Closure

DOE expects the closure phase to last from 2110 until 2125 for the Proposed Action with the low thermal load scenario. Although the staffing level for Inventory Module 1 or 2 would be the same as that for the Proposed Action (see Table 8-14), it would require more time. Closure would last 27 years for Module 1 or 2. Annualized impacts for about 520 repository workers would remain the same, carried forward for 12 more years. Cumulative impacts could occur between 2125 (the last year of Proposed Action closure) and 2137 (when Module 1 or 2 closure would be completed). However, as with the Proposed Action, because workforce demands would be considerably less than the peak during operation and monitoring, impacts to regional employment (direct and indirect), population, personal income, Gross Regional Product, and government expenditures for Module 1 or 2 probably would increase less than one-half of 1 percent. No substantial impacts would be likely during closure for Module 1 or 2.

8.2.6.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

Reasonably foreseeable future actions at the Nevada Test Site could affect the socioeconomic region of influence (Nye, Clark, and Lincoln Counties). The *Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all) presents various scenarios for Nevada Test Site actions. The Record of Decision for that EIS states that DOE would implement a combination of three alternatives: Expanded Use, No Action (continue operations at current levels) regarding mixed and low-level radioactive waste management, and Alternate Use of Withdrawn Lands regarding public education (61 *FR* 65551, December 13, 1996). Under this combination of alternatives, the Nevada Test Site could generate an increase of approximately 4,550 direct jobs, and most of these workers would be likely to live in Clark County (DOE 1996f, page 5-17). Because the Nevada Test Site jobs would be created by 2005, repository peak employment levels would occur later than the peak for Nevada Test Site employment and provide the communities affected with more time to assimilate any new residents that relocated to the region. Thus, no substantial impacts would be likely to occur.

8.2.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

This section discusses the short-term health and safety impacts to workers and to members of the public (radiological only) associated with construction, operation and monitoring, and closure activities at the Yucca Mountain site for Inventory Module 1 or 2 (Sections 8.2.7.1 through 8.2.7.3). Section 8.2.7.4 provides a summary of these impacts. Appendix F contains the approach and methods used to estimate the health and safety impacts and additional detailed results for Module 1 or 2 health and safety impacts to workers.

With one exception, no other Federal, non-Federal, or private actions were identified with spatially or temporally coincident short-term impacts in the region of influence that would result in cumulative health and safety impacts with those of the proposed Yucca Mountain Repository. Estimated radioactive releases from past activities at the Nevada Test Site resulted in very small radiation doses to the public (see Section 8.2.2.2.2); even combined with estimated radiation doses from a repository at Yucca Mountain, less than 1 latent cancer fatality would be likely (Section 8.2.7.4). With the increased number of persons living and working in the region, the number of injuries and fatalities from nonrepository-related activities would increase. However, injury and mortality incidence should remain unchanged or decrease, assuming the continued enforcement of occupational and public health and safety regulations.

Regarding the health and safety impact analysis for Inventory Module 1 or 2, the radiological characteristics of the spent nuclear fuel and high-level radioactive waste would be the same as those for the Proposed Action; there just would be more material to emplace. As described in Appendix A, the radioactive inventory (and radiological properties) of the Greater-Than-Class-C waste and

Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. Therefore, the subsurface emplacement of the material in Inventory Module 2 would not greatly increase radiological impacts to workers over those estimated for Module 1. For the surface facility evaluation, the number of workers would be the same for Inventory Module 1 or 2 (TRW 1999a, Section 3.3, third paragraph). Therefore, DOE did not perform separate impact analyses for Modules 1 and 2.

The primary changes in the parameters that would affect the magnitude of the worker health and safety impacts between the Proposed Action and Inventory Module 1 or 2 would be the periods required to perform the work (see Table 8-3) and the numbers of workers for the different phases. Appendix F (Table F-29) contains a detailed breakdown of the estimates for the involved and noninvolved workforce for the repository phases for Inventory Module 1 or 2 in terms of full-time equivalent worker-years.

For the public, the principal changes in parameters that would affect the magnitude of the health impact estimates would be the length of the various phases (see Table 8-3) and the rate at which air would be exhausted from the repository. The exhaust rate of the subsurface ventilation system would affect both the radon-222 concentrations to which subsurface workers would be exposed and the quantity of radon-222 released to the environment. Appendix G discusses radon-222 concentrations in the subsurface environment and release rates to the environment from the various project phases.

8.2.7.1 Construction

This section presents estimates of health and safety impacts to repository workers and members of the public for the 5-year construction phase. The values are similar to those for the Proposed Action because the length of the construction phase would be the same and activities would be similar.

Industrial Hazards

Table 8-15 lists health and safety hazards to workers common to the workplace. They are based on the health and safety loss statistics listed in Appendix F, Tables F-2 and F-3. For Inventory Module 1 or 2 these impacts would be independent of the thermal load scenarios because the number of workers would be the same for all three thermal load scenarios (see Appendix F, Table F-31).

Radiological Health Impacts

This analysis presents radiological health impacts in terms of doses and resultant latent cancer fatalities. Estimated doses were converted to estimates of latent cancer fatality using a dose-to-risk conversion factor of 0.0004 and 0.0005 latent cancer fatality per person-rem for workers and the public, respectively (see Appendix F, Section F.1.1.5).

Workers. Spent nuclear fuel and high-level radioactive waste would not be present during the construction phase. Potential radiological impacts to surface workers during this phase would be limited to those from releases of naturally occurring radon-222 and its decay products with the subsurface ventilation exhaust (these impacts are presented in Section 8.2, Table 8-9). Subsurface workers would incur exposure from radiation resulting from radionuclides in the walls of the drifts and from inhalation of radon-222 in the subsurface atmosphere. Surface worker exposure would be very small compared to those for subsurface workers. The radiological doses and health impacts for Inventory Module 1 or 2 are listed in Table 8-16. The Module 1 or 2 impacts would be independent of both thermal load and packaging scenarios because the subsurface workforce would not change.

Public. Potential radiological impacts to the public during the construction phase would be limited to those from the release of naturally occurring radon-222 with the exhaust from subsurface ventilation. For

Table 8-15. Construction phase (2005 to 2010) impacts to workers from industrial hazards.[a]

	Proposed Action[b]								
	High thermal load			Intermediate thermal load			Low thermal load		
Group	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
Total recordable cases	290	250	240	300	250	260	300	250	260
Lost workday cases	140	120	120	140	120	120	140	120	120
Fatalities	0.14	0.11	0.12	0.14	0.12	0.12	0.14	0.12	0.12
Noninvolved									
Total recordable cases	50	41	42	50	41	42	50	41	42
Lost workday cases	24	20	21	24	20	21	24	20	21
Fatalities	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
All workers (total)[f]									
Total recordable cases	340	290	280	350	290	300	350	290	300
Lost workday cases	160	140	140	170	140	140	170	140	140
Fatalities	0.18	0.15	0.16	0.18	0.16	0.16	0.18	0.16	0.16
	Inventory Module 1 or 2[g]								
				UC	DISP	DPC			
Involved									
Total recordable cases				300	250	260			
Lost workday cases				140	120	120			
Fatalities				0.14	0.12	0.12			
Noninvolved									
Total recordable cases				50	41	42			
Lost workday cases				24	20	21			
Fatalities				0.04	0.04	0.04			
All workers (total)[f]									
Total recordable cases				350	290	300			
Lost workday cases				170	140	140			
Fatalities				0.18	0.16	0.16			

a. The analysis assumes that construction would last 44 months for surface activities and 60 months for subsurface activities.
b. Source: Chapter 4, Table 4-20.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. Totals might differ from sums due to rounding.
g. Source: Appendix F, Tables F-7 and F-33.

Inventory Module 1 or 2, the construction phase and the subsurface exhaust system ventilation rate would be essentially the same as those for the Proposed Action. Thus, radiological health impacts to the public would be the same as those for the Proposed Action, as listed in Chapter 4, Table 4-22.

8.2.7.2 Operation and Monitoring

This section presents estimates of health and safety impacts to workers and members of the public during the operation and monitoring phase. The primary differences between Inventory Module 1 or 2 and the Proposed Action would be the longer durations for development and emplacement activities and the shorter duration for monitoring and maintenance activities (see Table 8-3). Under Module 1 or 2, it would take DOE 14 more years to complete drift development (36 years total) than for the Proposed Action and 14 more years to complete emplacement (38 years total) than for the Proposed Action. Because the analysis assumed that monitoring would end 100 years after the start of emplacement (or in 2110), the duration of the monitoring period would be shortened by 14 years (a total of 62 years) for Module 1 or 2 compared to the Proposed Action.

Table 8-16. Construction phase (2005 to 2010) radiological doses and health impacts to subsurface workers.[a]

Group	High thermal load	Intermediate thermal load	Low thermal load
		Proposed Action[b]	
Involved			
MEI[c] (millirem)	770	860	860
LCF[d] probability	0.0003	0.0003	0.0003
CD[e] (person-rem)	350	420	420
LCF incidence	0.14	0.17	0.17
Noninvolved			
MEI (millirem)	580	640	640
LCF probability	0.0002	0.0003	0.0003
CD (person-rem)	70	78	78
LCF incidence	0.03	0.03	0.03
All workers (total)[f]			
CD (person-rem)	420	500	500
LCF incidence	0.17	0.20	0.20
		Inventory Module 1 or 2[g]	
Involved			
MEI (millirem)		830	
LCF probability		0.0003	
CD (person-rem)		410	
LCF incidence		0.16	
Noninvolved			
MEI (millirem)		620	
LCF probability		0.0002	
CD (person-rem)		75	
LCF incidence		0.33	
All workers (total)[f]			
CD (person-rem)		480	
LCF incidence		0.19	

a. The construction phase would last 5 years. Results are for subsurface workers.
b. Source: Chapter 4, Table 4-21.
c. MEI = dose to maximally exposed individual worker.
d. LCF = latent cancer fatality.
e. CD = collective dose.
f. Totals might differ from sums due to rounding.
g. Source: Appendix F, Table F-34.

Industrial Hazards

Table 8-17 lists health and safety impacts to workers from industrial hazards common to the workplace. These impacts would be about 40 percent greater than those calculated for the Proposed Action.

Radiological Impacts

Workers. Table 8-10 lists radiation doses to workers and the public for this phase. Table 8-18 lists radiological doses and health impacts to workers during the operation and monitoring phase for Inventory Module 1 or 2. Appendix F contains additional detail and presents the radiological impacts for surface workers, subsurface workers, and monitoring activities. Radiological impacts to workers for Module 1 or 2 would be about 40 percent greater than those for the Proposed Action. The dominant factors in dose to workers are direct exposure and inhalation.

Public. Potential radiological impacts to the public from the operation and monitoring phase would result from the release of naturally occurring radon-22 and its decay products with the subsurface exhaust

Table 8-17. Operation and monitoring phase (2010 to 2110) impacts to workers from industrial hazards.

Group	High thermal load			Intermediate thermal load			Low thermal load		
	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DISP	DPC
	Proposed Action[d]								
Involved									
TRC[e]	1,360	1,150	1,160	1,360	1,150	1,160	1,400	1,180	1,200
LWC[f]	710	610	620	710	610	620	730	640	640
Fatalities	1.1	0.88	0.89	1.1	0.88	0.89	1.1	0.90	0.92
Noninvolved									
TRC	500	450	450	500	450	450	500	450	450
LWC	250	220	220	250	220	220	250	220	220
Fatalities	0.49	0.43	0.43	0.49	0.43	0.43	0.49	0.42	0.43
All workers (total)[g]									
TRC	1,860	1,590	1,610	1,860	1,590	1,610	1,890	1,630	1,650
LWC	950	840	840	950	840	840	950	860	870
Fatalities	1.6	1.3	1.3	1.6	1.3	1.3	1.6	1.3	1.3
	Inventory Module 1 or 2[h]								
Involved									
TRC	1,850	1,530	1,550	1,890	1,570	1,590	1,990	1,670	1,690
LWC	970	840	840	1,000	860	870	1,060	920	930
Fatalities	1.5	1.1	1.2	1.5	1.2	1.2	1.5	1.2	1.3
Noninvolved									
TRC	760	680	690	760	680	690	790	710	720
LWC	380	340	340	380	340	340	390	350	360
Fatalities	0.72	0.64	0.65	0.72	0.64	0.65	0.75	0.68	0.68
All workers (total)[g]									
TRC	2,610	2,210	2,240	2,650	2,250	2,280	2,780	2,380	2,410
LWC	1,350	1,170	1,180	1,380	1,200	1,210	1,400	1,270	1,280
Fatalities	2.2	1.8	1.8	2.2	1.8	1.8	2.3	1.9	1.9

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: Chapter 4, Table 4-23.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.
h. Source: Appendix F, sum of Tables F-35, F-36, and F-37.

ventilation air and from radioactive gases, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations.

Table 8-19 lists the total radiological doses and radiological health impacts to the public from releases to the atmosphere of krypton-85 and radon-222 during the operation and monitoring phase. Radon-222 and its decay products would be the dominant dose contributors (greater than 99 percent). Radiological health impacts would be 50 to 80 percent higher than those calculated for the Proposed Action.

8.2.7.3 Closure

This section contains estimates of health and safety impacts to workers and members of the public for the closure phase. The length of this phase would depend on the thermal load scenario (see Table 8-3).

Table 8-18. Operation and monitoring phase (2010 to 2110) radiological doses and health impacts to workers.

Group	High thermal load			Intermediate thermal load			Low thermal load		
	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DISP	DPC
	Proposed Action[d]								
Involved									
MEI[e] (millirem)	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[f] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[g] (person-rem)	8,120	5,330	5,380	8,450	5,660	5,710	8,530	5,740	5,790
LCF incidence	3.2	2.1	2.2	3.4	2.3	2.3	3.4	2.3	2.3
Noninvolved									
MEI (millirem)	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD (person-rem)	350	330	330	380	360	360	400	390	390
LCF incidence	0.14	0.13	0.13	0.15	0.14	0.14	0.16	0.15	0.15
All workers (total)[h]									
CD (person-rem)	8,470	5,660	5,710	8,830	6,020	6,070	8,930	6,130	6,180
LCF incidence	3.4	2.3	2.3	3.5	2.4	2.4	3.6	2.5	2.5
	Inventory Module 1 or 2[i]								
Involved									
MEI (millirem)	19,240	19,240	19,240	15,200	15,200	15,200	16,710	16,710	16,710
LCF probability	0.008	0.008	0.008	0.006	0.006	0.006	0.007	0.007	0.007
CD (person-rem)	11,690	7,320	7,390	11,420	7,050	7,120	12,280	7,910	7,980
LCF incidence	4.7	2.9	3.0	4.6	2.8	2.8	4.9	3.2	3.2
Noninvolved									
MEI (millirem)	7,700	7,700	7,700	5,450	5,450	5,450	7,550	7,550	7,550
LCF probability	0.003	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.003
CD (person-rem)	480	460	460	440	420	420	650	630	630
LCF incidence	0.19	0.18	0.18	0.18	0.17	0.17	0.26	0.25	0.25
All workers (total)[h]									
CD (person-rem)	12,180	7,780	7,850	11,860	7,470	7,530	12,930	8,540	8,610
LCF incidence	4.9	3.1	3.1	4.7	3.0	3.0	5.2	3.4	3.4

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: Chapter 4, Table 4-24.
e. MEI = dose to maximally exposed individual worker over a 50-year period. The subsurface facility workers during monitoring would incur the dose listed.
f. LCF = latent cancer fatality.
g. CD = collective dose.
h. Totals might differ from sums due to rounding.
i. Source: Sum of Appendix F, Tables F-39, F-40, F-41, and F-42.

Industrial Hazards

Table 8-20 lists health and safety impacts to workers from hazards common to the workplace. These impacts would be about 50 percent greater than those for the Proposed Action.

Radiological Impacts

Workers. Table 8-21 lists radiological doses and health impacts to workers during the closure phase. During the closure phase, the primary source of radiation exposure for surface workers would be inhalation of radon-222 released through the subsurface ventilation system. Subsurface workers would be exposed to radon-222 from inhalation of air in the drifts, to external radiation from radionuclides in the rock in the drift walls, and to external radiation emanating from the waste packages. Surface worker exposures would be much smaller than those to subsurface workers, so essentially all of the exposure and

Table 8-19. Operation and monitoring phase (2010 to 2110) radiological doses and health impacts to the public.

Dose[a]/impact	High thermal load	Intermediate thermal load	Low thermal load
	Proposed Action[b]		
Individual MEI[c] dose (millirem)	38	46	100
LCF[d] probability	1.9×10^{-5}	2.3×10^{-5}	5.1×10^{-5}
Population collective dose[e] (person-rem)	260	310	710
LCF incidence	0.13	0.15	0.35
	Inventory Module 1 or 2[f]		
Individual MEI dose (millirem)	68	67	170
LCF probability	3.4×10^{-5}	3.3×10^{-5}	8.4×10^{-5}
Population collective dose (person-rem)	470	460	1,200
LCF incidence	0.23	0.23	0.59

a. From releases of radon-222 and krypton-85 to the atmosphere.
b. Source: Chapter 4, Table 4-28.
c. MEI = the maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository for 24 years of operation and 46 years of monitoring for the Proposed Action and 38 years of operation and 32 years of monitoring for Inventory Module 1 or 2, for a total of 70 years.
d. LCF = latent cancer fatality.
e. Collective dose is for population within about 80 kilometers (50 miles) of Yucca Mountain.
f. Source: Table 8-10.

Table 8-20. Closure phase impacts to workers from industrial hazards.

	High thermal load			Intermediate thermal load			Low thermal load		
Group	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DPC	DISP
	Proposed Action[d]								
Involved									
TRC[e]	180	150	150	180	150	150	300	270	270
LWC[f]	85	71	74	85	71	74	140	130	130
Fatalities	0.08	0.07	0.07	0.08	0.07	0.07	0.14	0.13	0.13
Noninvolved									
TRC	28	23	24	28	23	24	41	36	37
LWC	14	11	12	14	11	12	20	18	18
Fatalities	0.03	0.02	0.02	0.03	0.02	0.02	0.04	0.03	0.03
All workers (total)[g]									
TRC	200	170	180	200	170	180	340	300	310
LWC	99	83	85	99	83	85	160	150	150
Fatalities	0.11	0.09	0.09	0.11	0.09	0.09	0.18	0.16	0.16
	Inventory Module 1 or 2[h]								
Involved									
TRC	270	240	250	320	300	300	460	430	440
LWC	130	120	120	160	140	140	220	210	210
Fatalities	0.13	0.12	0.11	0.15	0.14	0.14	0.22	0.20	0.21
Noninvolved									
TRC	38	33	34	44	38	40	59	53	54
LWC	19	16	17	22	19	19	29	26	27
Fatalities	0.03	0.03	0.03	0.04	0.03	0.03	0.05	0.05	0.05
All workers (total)[g]									
TRC	310	280	280	370	330	340	520	480	490
LWC	150	130	140	180	160	160	250	230	240
Fatalities	0.16	0.14	0.15	0.19	0.17	0.18	0.27	0.25	0.25

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: Chapter 4, Table 4-29.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.
h. Source: Sum of Appendix F, Tables F-43 and F-44.

Table 8-21. Closure phase radiological doses and health impacts to workers.

Group	High thermal load	Intermediate thermal load	Low thermal load
		Proposed Action[a]	
Involved			
MEI[b] (millirem)	2,040	2,370	5,520
LCF[c] probability	0.0008	0.0009	0.002
CD[d] (person-rem)	380	450	1,100
LCF incidence	0.15	0.18	0.44
Noninvolved			
MEI (millirem)	1,090	1,340	3,540
LCF probability	0.0004	0.0005	0.001
CD (person-rem)	48	59	160
LCF incidence	0.02	0.02	0.06
All workers (total)[e]			
CD (person-rem)	430	510	1,260
LCF incidence	0.17	0.20	0.50
		Inventory Module 1 or 2[f]	
Involved			
MEI (millirem)	5,200	5,280	9,450
LCF probability	0.002	0.002	0.004
CD (person-rem)	990	960	1,880
LCF incidence	0.40	0.38	0.75
Noninvolved			
MEI (millirem)	2,950	2,710	6,010
LCF probability	0.001	0.001	0.002
CD (person-rem)	130	120	260
LCF incidence	0.05	0.05	0.11
All workers (total)[e]			
CD (person-rem)	1,120	1,080	2,150
LCF incidence	0.45	0.43	0.86

a. Source: Chapter 4, Table 4-30.
b. MEI = dose to maximally exposed individual worker; a subsurface facilities worker could potentially incur the dose listed.
c. LCF = latent cancer fatality.
d. CD = collective dose.
e. Totals might differ from sums due to rounding.
f. Source: Full-time equivalent work years from Appendix F, Table F-21; exposure rates from radon inhalation, Table F-32, from waste package exposure, Table F-6, and from ambient exposure, Table F-5.

health impacts would be to subsurface workers. The primary source of exposure would be from inhalation of radon-222 and its decay products. Radiological impacts to workers from Inventory Module 1 or 2 would be greater than those for the Proposed Action by approximately 100 percent.

Public. Potential radiation-related health impacts to the public from closure activities would result from releases of radon-222 in the subsurface ventilation flow. Section 8.2.2.1.2 describes radiation doses to the public for this phase and they are listed in Table 8-11. Table 8-22 lists radiological dose and health impacts for the closure phase. Radiological health impacts to the public for the inventory module case would be approximately 300 to 400 percent greater than those for the Proposed Action and would be independent of the packaging scenario.

8.2.7.4 Summary

This section contains three summary tables:

- A summary of health impacts to workers from industrial hazards common to the workplace for all phases (Table 8-23)

Table 8-22. Closure phase radiological doses and health impacts to the public.

Dose[a]/impact	High thermal load	Intermediate thermal load	Low thermal load
	Proposed Action [b]		
Individual			
MEI[c] dose (millirem)	2.6	3.1	19
LCF[d] probability	1.3×10^{-6}	2.0×10^{-6}	9.4×10^{-6}
Population			
Collective dose[e] (person-rem)	13	15	93
LCF incidence	0.006	0.008	0.05
	Inventory Module 1 or 2[f]		
Individual			
MEI dose (millirem)	10	14	58
LCF probability	5.1×10^{-6}	6.8×10^{-6}	2.9×10^{-5}
Population			
Collective dose (person-rem)	51	68	290
LCF incidence	0.025	0.034	0.14

a. From releases of radon-222 and krypton-85 to the atmosphere.
b. Source: Chapter 4, Table 4-31.
c. MEI = maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository for total closure period.
d. LCF = latent cancer fatality.
e. Collective dose is for population within about 80 kilometers (50 miles) of Yucca Mountain.
f. Source: Table 8-11.

- A summary of radiological doses and health impacts to workers for all phases (Table 8-24)
- A summary of radiological doses and health impacts to the public for all phases (Table 8-25)

Industrial Hazards to Workers

Table 8-23 summarizes health and safety impacts to workers from industrial hazards common to the workplace for all phases. The calculated health impacts from industrial hazards common to the workplace would be in the range of 2 to 3 fatalities for Inventory Module 1 or 2. Most of the impacts would come from surface facility operations during the operation and monitoring phase. The next biggest contributor would be from emplacement drift development during the operation and monitoring phase. These two activities would account for more than 80 percent of the health and safety impacts from industrial hazards (see Appendix F, Table F-31). Industrial safety impacts for Module 1 or 2 are about 40 percent greater than those for the Proposed Action.

Radiological Health

Workers. Table 8-24 summarizes radiological doses and health impacts to workers for the Proposed Action and Inventory Module 1 or 2. It lists these impacts as the likelihood of a latent cancer fatality for the maximally exposed individual worker over a 50-year working career, and as the number of latent cancer fatalities. The calculated values for latent cancer fatalities for repository workers during the construction, operation and monitoring, and closure phases for Module 1 or 2 are in the range of 4 to 6 fatalities for Module 1 or 2. These are higher than those for the Proposed Action (2.5 to 4 fatalities) and would be about double those from normal workplace industrial hazards (see Table 8-23).

About 50 percent of the total worker radiation dose would be from the receipt and handling of spent nuclear fuel in the surface facilities. Radiation exposure from inhalation of radon-222 and its decay products by workers in the subsurface facilities would account for about 25 percent of total worker dose, with another 10 to 15 percent of the dose coming from subsurface worker exposure to radiation emanating from the waste packages.

Public. Table 8-25 summarizes radiological doses and health impacts to the public during all phases for the Proposed Action and Inventory Module 1 or 2. The radiological doses and health impacts would

Table 8-23. Estimated impacts to workers from industrial hazards during all phases.

Group	High thermal load			Intermediate thermal load			Low thermal load		
	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DISP	DPC
	Proposed Action[d]								
Involved									
TRC[e]	1,820	1,540	1,560	1,830	1,550	1,570	1,990	1,700	1,730
LWC[f]	930	800	810	930	810	820	1,010	890	900
Fatalities	1.3	1.1	1.1	1.3	1.1	1.1	1.4	1.2	1.2
Noninvolved									
TRC	570	510	520	570	510	520	590	520	530
LWC	280	250	260	280	250	260	290	260	260
Fatalities	0.54	0.48	0.49	0.54	0.48	0.49	0.55	0.50	0.50
All workers (total)[g]									
TRC	2,400	2,050	2,080	2,410	2,060	2,090	2,580	2,230	2,260
LWC	1,210	1,065	1,070	1,220	1,060	1,070	1,280	1,140	1,160
Fatalities	1.8	1.5	1.6	1.8	1.5	1.6	1.9	1.6	1.7
	Inventory Module 1 or 2[h]								
Involved									
TRC	2,420	2,020	2,060	2,510	2,120	2,150	2,740	2,350	2,380
LWC	1,240	1,070	1,090	1,500	1,120	1,140	1,420	1,250	1,260
Fatalities	1.7	1.4	1.4	1.8	1.4	1.5	1.9	1.6	1.6
Noninvolved									
TRC	850	750	760	850	760	770	900	800	810
LWC	420	370	380	420	380	380	450	400	400
Fatalities	0.79	0.71	0.72	0.80	0.72	0.72	0.84	0.76	0.77
All workers (total)[g]									
TRC	3,260	2,780	2,820	3,360	2,880	2,920	3,640	3,160	3,200
LWC	1,670	1,450	1,460	1,720	1,500	1,520	1,820	1,650	1,670
Fatalities	2.5	2.1	2.1	2.6	2.1	2.2	2.7	2.3	2.4

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: Chapter 4, Table 4-32.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.
h. Source: Sum of Tables 8-15, 8-17, and 8-20.

result from exposure of the public to naturally occurring radon-222 and decay products released from the subsurface facilities in ventilation exhaust air. The calculated likelihood for Module 1 or 2 that the maximally exposed individual would experience a latent cancer fatality is less than 0.00005. The estimated increase in the number of latent cancer fatalities is less than 1 for the exposed population within about 80 kilometers (50 miles) over the period of more than 100 years of repository activities.

For purposes of comparison, the number of latent cancer fatalities calculated for the public for the Yucca Mountain construction, operation and monitoring, and closure phases for Inventory Module 1 or 2 would be less than 0.75. The average annual age-adjusted rate for cancer deaths is 185 per 100,000 Nevada residents (ACS 1998, page 6). Assuming this mortality rate is a baseline that would remain unchanged for the estimated population of 28,000 people living within about 80 kilometers of Yucca Mountain, the expected annual cancer death rate in the population would be about 50 per year. Therefore, there would be more than 5,000 cancer deaths from other causes over the period of repository operations.

Table 8-24. Estimated radiological doses and health impacts to workers during all phases.

Group	High thermal load			Intermediate thermal load			Low thermal load		
	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DISP	DPC
	Proposed Action[d]								
Involved									
MEI[e] (millirem)	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[f] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[g] (person-rem)	8,850	6,060	6,110	9,320	6,530	6,580	10,060	7,270	7,320
LCF[h] incidence	3.5	2.4	2.4	3.7	2.6	2.6	4.0	2.9	2.9
Noninvolved									
MEI (millirem)	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD (person-rem)	460	450	450	510	500	500	640	620	620
LCF incidence	0.19	0.18	0.18	0.21	0.20	0.20	0.25	0.25	0.25
All workers (total)[i]									
CD (person-rem)	9,320	6,510	6,560	9,830	7,030	7,080	10,690	7,890	7,940
LCF incidence	3.7	2.6	2.6	3.9	2.8	2.8	4.3	3.2	3.2
	Inventory Module 1 or 2[j]								
Involved									
MEI (millirem)	19,240	19,240	19,240	15,200	15,200	15,200	16,710	16,710	16,710
LCF probability	0.008	0.008	0.008	0.006	0.006	0.006	0.007	0.007	0.007
CD (person-rem)	13,090	8,720	8,790	12,780	8,420	8,480	14,570	10,200	10,270
LCF incidence	5.2	3.5	3.5	5.1	3.4	3.4	5.8	4.1	4.1
Noninvolved									
MEI (millirem)	7,700	7,700	7,700	5,450	5,450	5,450	7,550	7,550	7,550
LCF probability	0.003	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.003
CD (person-rem)	690	660	660	640	610	610	990	970	970
LCF incidence	0.28	0.27	0.27	0.26	0.24	0.24	0.40	0.39	0.39
All workers (total)[i]									
CD (person-rem)	13,780	9,380	9,450	13,420	9,030	9,100	15,560	11,170	11,240
LCF incidence	5.5	3.8	3.8	5.4	3.6	3.6	6.2	4.5	4.5

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: Chapter 4, Table 4-33.
e. MEI = dose to maximally exposed individual worker over a 50-year period; subsurface facility workers during the monitoring phase would incur the listed impacts.
f. LCF = latent cancer fatality.
g. CD = collective dose.
h. LCF = latent cancer fatality incidence.
i. Totals might differ from sums due to rounding.
j. Source: Sum of Tables 8-16, 8-18, and 8-21.

Table 8-25. Estimated radiological doses and health impacts to the public during all phases.

Dose[a]/impact	High thermal load	Intermediate thermal load	Low thermal load
	Proposed Action[b]		
Individual MEI[c] dose (millirem)	38	46	100
LCF[d] probability	1.9×10^{-5}	2.3×10^{-5}	5.1×10^{-5}
Population collective dose[e] (person-rem)	280	340	810
LCF incidence	0.14	0.17	0.41
	Inventory Module 1 or 2[f]		
Individual MEI dose (millirem)	68	67	170
LCF probability	3.4×10^{-5}	3.3×10^{-5}	8.5×10^{-5}
Population collective dose (person-rem)	530	540	1,500
LCF incidence	0.27	0.27	0.74

a. From releases of radon-222 and krypton-85 to the atmosphere.
b. Source: Chapter 4, Table 4-34.
c. MEI = the maximally exposed individual of the public, 20 kilometers (12 miles) south of the repository. Over a 70-year lifetime of an individual, this maximum dose occurs during the operation and monitoring phase.
d. LCF = latent cancer fatality.
e. Collective dose is for the population within about 80 kilometers (50 miles) of Yucca Mountain over all phases [that is, over a period from 118 to 132 years for Inventory Module 1 or 2].
f. Source: Sum of Tables 8-19 and 8-22, and Chapter 4, Table 4-22.

8.2.8 ACCIDENTS

Disposal in the proposed repository of the additional spent nuclear fuel and high-level radioactive waste along with the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in Inventory Module 1 or 2 would result in a very small increase in the estimated risk from accidents described in Chapter 4, Section 4.1.8, for the Proposed Action. The potential hazards and postulated accident scenarios identified and evaluated in Chapter 4, Section 4.1.8, would be the same as those for Module 1 or 2 because there would be no change to the basic repository design or operation. The time required for receipt, packaging, and emplacement of the additional waste would extend from 24 to 38 years, but the probability of an accident scenario (likelihood per year) would be essentially unaffected. The accident scenario consequences evaluated for the Proposed Action would bound those that could occur for Inventory Module 1 or 2 because the spent nuclear fuel and high-level radioactive waste, except the Greater-Than-Class-C waste and the Special-Performance-Assessment-Required waste, would be the same. DOE has not determined the final disposition method for Greater-Than-Class-C and Special-Performance-Assessment-Required waste but, based on the characteristics and expected packaging of these wastes (type and quantity of radionuclides; see Appendix A), the accident scenario consequences calculated in Chapter 4, Section 4.1.8 for spent nuclear fuel and high-level radioactive waste would be bounding. Therefore, substantial cumulative accident impacts would be unlikely for Inventory Module 1 or 2.

In addition, the analysis identified no other Federal, non-Federal, or private action that could affect either the occurrence probability in consequences of the accident scenarios evaluated above.

8.2.9 NOISE

The emplacement of Inventory Module 1 or 2 would have noise levels associated with the construction and operation of the repository similar to those for the Proposed Action. An increase in potential noise impacts from Module 1 or 2 would result only from the increased number of shipments to the site. The expected rate of receipt would be about the same as that for the Proposed Action; therefore, the impact would be an extended period (approximately 14 years) that shipping would continue beyond the Proposed Action.

DOE does not expect other Federal, non-Federal, or private actions in the region to add measurable noise impacts to those of the Proposed Action or Inventory Module 1 or 2.

8.2.10 AESTHETICS

There would be no impacts for Inventory Module 1 or 2 beyond those described in Chapter 4, Section 4.1.10, because the profile of the repository facility would not be visible beyond the analyzed land withdrawal area boundary. DOE does not expect other Federal, non-Federal, and private industry actions in the region to add measurable aesthetic impacts to those of the Proposed Action or Inventory Module 1 or 2.

8.2.11 UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to utilities, energy, materials, and site services from the construction, operation and monitoring, and closure of the repository for Inventory Module 1 or 2. The scope of the analysis includes electricity use, fossil-fuel consumption, and consumption of construction materials. Chapter 4, Section 4.1.11, evaluates special services such as emergency medical support, fire protection, and security and law enforcement, which would not change for Module 1 or 2. The material in this section parallels Section 4.1.11, which addresses impacts from the Proposed Action. DOE has not

identified any other Federal, non-Federal, or private actions that would result in cumulative impacts to utilities, energy, materials, and site services.

To determine the potential impacts of Inventory Module 1 or 2, DOE evaluated the projected uses of electricity, fuel, and construction materials for each repository phase and compared them to those for the Proposed Action. The following paragraphs describe these evaluations.

Construction

As in the Proposed Action, the major impact during the construction phase for Inventory Module 1 or 2 would be the estimated demand for electric power. The peak demand for electricity for the Proposed Action would be 24 megawatts during construction (Table 8-26). During the construction required for Module 1 or 2, the peak demand for electricity would be about the same (24 to 25 megawatts). The tunnel boring machines would account for more than half of the demand for electricity during the 5-year construction phase, but power would also be required to operate ventilation equipment and to support the construction of surface facilities. As for the Proposed Action, the existing electric transmission and distribution system at the Nevada Test Site could not support this increased demand. DOE is evaluating modifications to the site electrical system, as discussed in Chapter 4, Section 4.1.11.

Table 8-26. Peak electric power demand (megawatts).[a,b]

Phase[c]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[d]	DISP[e]	DPC[f]	UC	DISP	DPC	UC	DISP	DPC
					Proposed Action[g]					
Construction	*2005-2010*	*24*	*24*	*24*	*24*	*24*	*24*	*24*	*24*	*24*
Operation and monitoring	*2010-2033*	*41*	*38*	*38*	*41*	*38*	*38*	*41*	*38*	*38*
Development	2010-2032	19	19	19	19	19	19	19	19	19
Emplacement	2010-2033	22	18	19	22	18	19	22	18	19
Decontamination	2034-2037	14	10	11	14	10	11	14	10	11
Monitoring	2034-2110	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2060	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2310	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Closure	*2110+6-15*	*9.2*	*8.9*	*8.9*	*9.2*	*8.9*	*8.9*	*9.2*	*8.9*	*8.9*
					Inventory Module 1 or 2[g]					
Construction	*2005-2010*	*25*	*24*	*24*	*25*	*24*	*24*	*25*	*24*	*24*
Operation and monitoring	*2010-2048*	*41*	*37*	*38*	*41*	*37*	*38*	*41*	*37*	*38*
Development	2010-2046	19	19	19	19	19	19	27	27	27
Emplacement	2010-2048	22	18	19	22	18	19	22	18	19
Decontamination	2048-2051	14	10	11	14	10	11	14	10	11
Monitoring	2048-2110	8	8	8	8	8	8	8	8	8
Closure	*2110+11-27*	*9.5*	*9.2*	*9.2*	*9.5*	*9.2*	*9.2*	*9.5*	*9.2*	*9.2*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. Totals might differ from sums due to rounding.
c. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 27 years for Inventory Module 1 or 2.
d. UC = uncanistered packaging scenario.
e. DISP = disposable canister packaging scenario.
f. DPC = dual-purpose canister packaging scenario.
g. The estimated electric power demand from a collocated Cask Maintenance Facility would be within the repository's capacity.

The use of electricity for Inventory Module 1 or 2 would be about 240,000 megawatt-hours during the construction phase, compared to 180,000 to 240,000 megawatt-hours for the Proposed Action (see Table 8-27). This is about 30 percent above the Proposed Action. All thermal load scenarios for Module 1 or 2 would involve the construction of main drifts longer than those for the Proposed Action.

Table 8-27. Electricity use (1,000 megawatt-hours)[a,b]

Phase[c]	Time (years)	High thermal load UC[d]	High thermal load DISP[e]	High thermal load DPC[f]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
					Proposed Action[g]					
Construction	*2005-2010*	*180*	*180*	*180*	*230*	*230*	*230*	*240*	*240*	*240*
Operation and monitoring	*2010-2110*	*5,500*	*4,900*	*5,000*	*6,100*	*5,600*	*5,600*	*8,600*	*8,000*	*8,100*
Development	2010-2032	650	650	650	890	890	890	2,200	2,280	2,200
Emplacement	2010-2033	2,600	2,100	2,100	2,600	2,100	2,100	2,600	2,100	2,200
Decontamination	2034-2037	250	190	200	250	190	200	250	190	200
Monitoring	2034-2110	2,000	2,000	2,000	2,400	2,400	2,400	3,500	3,500	3,500
	2034-2060	680	680	680	810	810	810	1,200	1,200	1,200
	2034-2310	7,200	7,200	7,200	8,600	8,600	8,600	13,000	13,000	13,000
Closure	*2110+6-15*	*250*	*240*	*240*	*370*	*370*	*370*	*560*	*560*	*560*
					Inventory Module 1 or 2[g]					
Construction	*2005-2010*	*240*	*240*	*240*	*240*	*240*	*240*	*240*	*240*	*240*
Operation and monitoring	*2010-2110*	*8,400*	*7,500*	*7,600*	*9,200*	*8,400*	*8,500*	*17,000*	*16,000*	*16,000*
Development	2010-2046	1,400	1,400	1,400	1,700	1,700	1,700	6,100	6,100	6,100
Emplacement	2010-2048	4,100	3,300	3,400	4,200	3,400	3,500	4,400	3,600	3,700
Decontamination	2048-2051	250	190	200	250	190	200	250	190	200
Monitoring	2048-2110	2,600	2,600	2,600	3,100	3,100	3,100	6,200	6,200	6,200
Closure	*2110+11-27*	*480*	*470*	*480*	*620*	*620*	*620*	*1,800*	*1,700*	*1,700*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. Totals might differ from sums due to rounding.
c. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 27 years for Inventory Module 1 or 2.
d. UC = uncanistered packaging scenario.
e. DISP = disposable canister packaging scenario.
f. DPC = dual-purpose canister packaging scenario.
g. The additional electricity used as a result of Cask Maintenance Facility construction, operation and monitoring, and closure activities would be no greater than approximately 10 percent of that for the repository.

The use of liquid fossil fuel during the construction phase would include diesel fuel and fuel oil. The estimated liquid petroleum use would be 24 to 25 million liters (6.3 to 6.6 million gallons) compared to 7.1 to 14 million liters (1.9 to 3.7 million gallons) for the Proposed Action (see Table 8-28). The usage rate should be well within the regional supply capacity and, therefore, would not result in substantial impacts.

The primary materials needed to support construction would be concrete, steel, and copper. Concrete would be used for tunnel liners. Concrete also would be used in the construction of the surface facilities. The quantity of concrete required for the surface facilities and initial emplacement drift construction would be about 400,000 cubic meters (523,000 cubic yards). Sand and gravel needs would be met from materials excavated from the repository. The value would be about 5 to 20 percent higher than that for the Proposed Action. As much as 190,000 metric tons (210,000 tons) of steel for a variety of uses including rebar, piping, vent ducts, and track, and 100 metric tons (110 tons) of copper for electrical cable also would be required. These quantities would not be likely to affect the regional supply capacity.

Operation and Monitoring

The event that would indicate the start of the operation and monitoring phase would be the beginning of emplacement of spent nuclear fuel and high-level radioactive waste. During this phase the construction of emplacement drifts would continue in parallel with emplacement activities at about the same rate as during the construction phase. As a result, the peak electric power demand would increase to between about 37 and 41 megawatts. The peak demand of 41 megawatts would be about the same as that for the Proposed Action. As was the case for the Proposed Action, DOE would have to upgrade or revise the

Table 8-28. Fossil-fuel use (million liters).[a,b,c]

Phase[d]	Time (years)	High thermal load UC[e]	High thermal load DISP[f]	High thermal load DPC[g]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
		Proposed Action[h]								
Construction	*2005-2010*	*8.1*	*7.1*	*7.3*	*12*	*11*	*12*	*14*	*13*	*13*
Operation and monitoring	*2010-2110*	*290*	*240*	*240*	*290*	*250*	*250*	*360*	*310*	*310*
Development	2010-2032	19	19	19	20	20	20	83	83	83
Emplacement	2010-2033	230	180	190	230	180	190	230	180	190
Decontamination	2034-2037	33	26	27	33	26	27	33	26	27
Monitoring	2034-2110	11	11	11	15	15	15	15	15	15
	2034-2060	3.9	3.9	3.9	5.0	5.0	5.0	5.0	5.0	5.0
	2034-2310	41	41	41	53	53	53	53	53	53
Closure	*2110+6-15*	*5.1*	*4.5*	*4.6*	*9.4*	*8.8*	*8.9*	*15*	*14*	*15*
		Inventory Module 1 or 2[h]								
Construction	*2005-2010*	*25*	*24*	*24*	*25*	*24*	*24*	*25*	*24*	*24*
Operation and monitoring	*2010-2110*	*450*	*370*	*380*	*470*	*410*	*400*	*580*	*500*	*510*
Development	2010-2046	45	45	45	70	70	70	170	170	170
Emplacement	2010-2048	360	290	300	360	290	300	360	290	300
Decontamination	2048-2051	33	26	27	33	26	27	33	26	27
Monitoring	2048-2110	12	12	12	12	12	12	12	12	12
Closure	*2110+11-27*	*13*	*12*	*12*	*17*	*16*	*16*	*32*	*31*	*31*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. To convert liters to gallons, multiply by 0.26418.
c. Totals might differ from sums due to rounding.
d. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 27 years for Inventory Module 1 or 2.
e. UC = uncanistered packaging scenario.
f. DISP = disposable canister packaging scenario.
g. DPC = dual-purpose canister packaging scenario.
h. The additional fossil fuel used as a result of Cask Maintenance Facility construction, operation and monitoring, and closure activities would be no greater than approximately 10 percent of that for the repository.

transmission and distribution system on the Nevada Test Site to meet this demand. However, the upgrade or revision for the Proposed Action would accommodate the similar increase for Inventory Module 1 or 2.

The demand for electricity for Inventory Module 1 or 2 would be well within the regional capacity for power generation. Nevada Power Company, for example, plans to maintain a reserve capacity of about 12 percent. For the beginning of the operation and monitoring phase in 2010, Nevada Power projects a net peak load of about 6,000 megawatts and plans a reserve of about 710 megawatts (NPC 1997, Figure 4, page 9). The repository peak demand of 41 megawatts would be less than 1 percent of the Nevada Power Company planned capacity and about 7 percent of planned reserves. The repository would not affect the regional availability of electric power to any extent.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It should range between 370 million and 580 million liters (98 million and 153 million gallons) during repository operations. The annual usage rates would be highest during the first half of the operation and monitoring phase (emplacement and continued construction of drifts) and would decrease substantially during the monitoring period (see Table 8-28). The projected annual usage rates of liquid fossil fuels would be higher than those for the Proposed Action but would still be within the regional supply capacity.

Additional construction materials would be required to support the continued construction of emplacement drifts for Inventory Module 1 or 2. About 3,300,000 cubic meters (4,300,000 cubic yards) of concrete would be required for the low thermal load scenario, and 910,000 cubic meters (1,200,000 cubic yards) would be required for the high thermal load scenario (see Table 8-29). The requirement for

Table 8-29. Concrete use (1,000 cubic meters).[a,b,c]

Phase[d]	Time (years)	High thermal load UC[e]	High thermal load DISP[f]	High thermal load DPC[g]	Intermediate thermal load UC	Intermediate thermal load DISP	Intermediate thermal load DPC	Low thermal load UC	Low thermal load DISP	Low thermal load DPC
		Proposed Action[h]								
Construction	*2005-2010*	*330*	*330*	*330*	*390*	*380*	*380*	*390*	*390*	*390*
Operation and monitoring	*2010-2110*	*450*	*450*	*450*	*510*	*510*	*510*	*1,800*	*1,800*	*1,800*
Development	2010-2032	420	420	420	480	480	480	1,700	1,700	1,700
Emplacement	2010-2033	27	27	27	27	27	27	27	27	27
Closure	*2110+6-15*	*2*	*2*	*2*	*2*	*2*	*2*	*4*	*4*	*4*
Totals		***780***	***780***	***780***	***900***	***890***	***890***	***2,200***	***2,200***	***2,200***
		Inventory Module 1 or 2[h]								
Construction	*2005-2010*	*400*	*400*	*400*	*400*	*400*	*400*	*400*	*400*	*400*
Operation and monitoring	*2010-2110*	*910*	*910*	*910*	*1,200*	*1,200*	*1,200*	*3,300*	*3,300*	*3,300*
Development	2010-2046	870	870	870	1,100	1,100	1,100	3,200	3,200	3,200
Emplacement	2010-2048	45	45	45	45	45	45	110	110	110
Closure	*2110+11-27*	*3*	*3*	*3*	*5*	*5*	*5*	*8*	*8*	*8*
Totals		***1,300***	***1,300***	***1,300***	***1,600***	***1,600***	***1,600***	***3,700***	***3,700***	***3,700***

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-17 to 6-24).
b. To convert cubic meters to cubic yards, multiply by 1.3079.
c. Totals might differ from sums due to rounding.
d. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 24 years for Inventory Modules 1 or 2.
e. UC = uncanistered packaging scenario.
f. DISP = disposable canister packaging scenario.
g. DPC = dual-purpose canister packaging scenario.
h. The additional concrete used as a result of Cask Maintenance Facility construction, operation and monitoring, and closure activities would be no greater than approximately 10 percent of that for the repository.

steel would be between 300,000 and 1,400,000 metric tons (330,000 and 1,540,000 tons), and for copper it would be about 300 and 1,600 metric tons (330 and 1,800 tons) (see Tables 8-30 and 8-31). These quantities, while 2 or 3 times those required for the Proposed Action, would be unlikely to affect the regional supply capacity because the annual usage rate would be only about 20 to 30 percent higher than that for the Proposed Action.

Closure

The peak electric power required during the closure phase for Inventory Module 1 or 2 would be only slightly higher than that for the Proposed Action and would be less than 10 megawatts for all three thermal load scenarios. This would be much less than the peak levels predicted for the earlier phases, so impacts would be small.

Fossil-fuel use would be between 12 million and 32 million liters (3.2 million and 8.5 million gallons). A small amount of concrete and steel would be used for closure. An estimated maximum of 8,000 cubic meters (10,000 cubic yards) of concrete would be required for the low thermal load scenario and about 3,000 cubic meters (3,900 cubic yards) for the high thermal load scenario. Similarly, an estimated 3,700 metric tons (4,100 tons) of steel would be required for the low thermal load scenario and about 1,400 metric tons (1,500 tons) for the high thermal load scenario. The fossil-fuel and material quantities required for closure would not be large and would not result in substantial impacts.

Table 8-30. Steel use (1,000 metric tons).[a,b,c]

Phase[d]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[e]	DISP[f]	DPC[g]	UC	DISP	DPC	UC	DISP	DPC
		Proposed Action[h]								
Construction	*2005-2010*	*70*	*68*	*67*	*83*	*81*	*80*	*83*	*81*	*80*
Operation and monitoring	*2010-2110*	*130*	*130*	*130*	*180*	*180*	*180*	*720*	*720*	*720*
Development	2010-2032	90	90	90	140	140	140	610	610	610
Emplacement	2010-2033	42	42	42	42	42	42	110	110	110
Closure	*2110+6-15*	*0.71*	*0.71*	*0.71*	*0.92*	*0.92*	*0.92*	*2.0*	*2.0*	*2.0*
Totals		***200***	***200***	***200***	***260***	***260***	***260***	***800***	***800***	***800***
		Inventory Module 1 or 2[h]								
Construction	*2005-2010*	*190*	*190*	*190*	*190*	*190*	*190*	*190*	*190*	*190*
Operation and monitoring	*2010-2110*	*300*	*300*	*300*	*370*	*370*	*370*	*1,400*	*1,400*	*1,400*
Development	2010-2046	230	230	230	300	300	300	1,200	1,200	1,200
Emplacement	2010-2033	70	70	70	70	70	70	180	180	180
Closure	*2110+11-27*	*1.4*	*1.4*	*1.4*	*2.1*	*2.1*	*2.1*	*3.7*	*3.7*	*3.7*
Totals		***490***	***490***	***490***	***560***	***560***	***560***	***1,600***	***1,600***	***1,600***

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-17 to 6-24)
b. To convert metric tons to tons, multiply by 1.1023.
c. Totals might differ from sums due to rounding.
d. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 27 years for Inventory Modules 1 or 2.
e. UC = uncanistered packaging scenario.
f. DISP = disposable canister packaging scenario.
g. DPC = dual-purpose canister packaging scenario.
h. The additional steel used as a result of Cask Maintenance Facility construction, operation and monitoring, and closure activities would be no greater than approximately 10 percent of that for the repository.

Table 8-31. Copper use (1,000 metric tons).[a,b,c]

Phase[d]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[e]	DISP[f]	DPC[g]	UC	DISP	DPC	UC	DISP	DPC
		Proposed Action[h]								
Construction	2005-2010	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operation and monitoring										
Development[i]	2010-2032	0.1	0.1	0.1	0.1	0.1	0.1	0.9	0.9	0.9
Closure	2110+6-15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals		***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***1.0***	***1.0***	***1.0***
		Inventory Module 1 or 2[h]								
Construction	2005-2010	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operation and monitoring										
Development	2010-2046	0.3	0.3	0.3	0.3	0.3	0.3	1.6	1.6	1.6
Closure	2110+11-27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals		***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***1.7***	***1.7***	***1.7***

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. To convert metric tons to tons, multiply by 1.1023.
c. Totals might differ from sums due to rounding.
d. Approximate periods for each phase would be as follows: construction, 5 years; operation and monitoring, 100 years; closure, 6 to 15 years for the Proposed Action and 11 to 27 years for Inventory Module 1 or 2.
e. UC = uncanistered packaging scenario.
f. DISP = disposable canister packaging scenario.
g. DPC = dual-purpose canister packaging scenario.
h. The additional copper used as a result of Cask Maintenance Facility construction, operation and monitoring, and closure activities would be no greater than approximately 10 percent of that for the repository.
i. Copper would not be consumed during other portions of the operation and monitoring phase.

8.2.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

8.2.12.1 Inventory Module 1 or 2 Impacts

Activities for the emplacement of Inventory Module 1 or 2 would generate waste totals beyond the quantities estimated for the Proposed Action (see Chapter 4, Section 4.1.12). The waste types and the treatment and disposal of each waste type would be the same as those described for the Proposed Action.

The quantities of most waste types for Inventory Module 1 or 2 would not change in comparison to the Proposed Action during the construction phase. Sanitary sewage and industrial wastewater would have small fluctuations in comparison to the Proposed Action (TRW 1999a, page 73; TRW 1999b, pages 6-8, 6-9, 6-48, and 6-49).

The emplacement of Inventory Module 1 or 2 would require an additional 14 years of activities, which would reduce the number of maintenance and monitoring years from 76 to 62 years. Table 8-32 lists the waste quantities generated for the Proposed Action and Inventory Modules 1 and 2 for the operation and monitoring phase.

The closure of the repository after the emplacement of the Inventory Module 1 or 2 inventory would require more time than the Proposed Action. The number of years needed for closure would also increase with the lower thermal load scenarios. (Table 8-33 lists the difference in time sequences.) The additional time would lead to an increase in waste quantities.

Sanitary and industrial solid waste, sanitary sewage, and industrial wastewater would be disposed of in facilities at the repository site. These facilities would be designed to accommodate the additional waste from Inventory Module 1 or 2. However, DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction and demolition debris and sanitary and industrial solid waste. If Nevada Test Site landfills were used, about 290,000 cubic meters (10.2 million cubic feet) to 440,000 cubic meters (15.5 million cubic feet) would be disposed of from construction through closure (TRW 1999a, Section 6; TRW 1999b, Section 6). Disposal of the Proposed Action waste quantities would require the Nevada Test Site landfills to operate past their projected operating lives and to expand as needed (Chapter 4, Section 4.1.12.2). Disposal of the larger waste quantities under Inventory Module 1 or 2 would require the availability of additional disposal capacity in future landfill expansions.

Impacts from the treatment and disposal of hazardous waste off the site would be the same for the Proposed Action and Inventory Module 1 or 2. At present, commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year (1993 to 2013) available capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states is about 7 times more than the demand for these services. The estimated landfill capacity is about 50 times the demand. Given the current outlook for the capacity versus demand for hazardous waste treatment and disposal, the treatment and disposal of repository-generated hazardous waste would not present a large cumulative impact.

The Nevada Test Site has an estimated total disposal capacity of 3.15 million cubic meters (110 million cubic feet). The DOE analysis of demand for low-level radioactive waste disposal at the Nevada Test Site through 2070 projects a need for about 670,000 cubic meters (24 million cubic feet or 2.8 percent) of the total disposal capacity (DOE 1998l, page 2-23). The reserve capacity at the Nevada Test Site is about 2.5 million cubic meters (88 million cubic feet). The disposal of repository-generated waste would

Table 8-32. Estimated operation and monitoring phase (2010 to 2110) waste quantities.[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
	Proposed Action								
Low-level radioactive (cubic meters)[e]	68,000	19,000	26,000	68,000	19,000	26,000	68,000	19,000	26,000
Hazardous (cubic meters)	6,100	2,400	2,300	6,100	2,400	2,300	6,100	2,400	2,300
Sanitary and industrial solid (cubic meters)	70,000	60,000	61,000	70,000	60,000	61,000	90,000	80,000	81,000
Sanitary sewage (million liters)[f]	1,800	1,500	1,600	1,800	1,500	1,600	1,800	1,600	1,600
Industrial wastewater (million liters)	900	780	780	930	810	810	1,400	1,300	1,300
	Inventory Module 1								
Low-level radioactive (cubic meters)	110,000	37,000	42,000	110,000	37,000	42,000	110,000	37,000	42,000
Hazardous (cubic meters)	9,800	3,800	3,500	9,800	3,800	3,500	9,800	3,800	3,500
	Inventory Module 2								
Low-level radioactive (cubic meters)	130,000	41,000	46,000	130,000	41,000	46,000	130,000	41,000	46,000
Hazardous (cubic meters)	12,000	4,600	4,300	12,000	4,600	4,300	12,000	4,600	4,300
	Inventory Module 1 or 2								
Sanitary and industrial solid (cubic meters)	92,000	79,000	80,000	92,000	79,000	80,000	120,000	110,000	110,000
Sanitary sewage (million liters)	2,300	2,000	2,000	2,300	2,000	2,000	2,500	2,100	2,200
Industrial wastewater (million liters)	1,400	1,300	1,300	1,500	1,300	1,300	2,200	2,000	2,000

a. Sources: Chapter 4, Section 4.1.12; TRW (1999a, pages 78, 80, and 81); TRW (1999b, pages 6-56, 6-62, 6-67, and 6-68).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

require about 2.8 percent of the reserve capacity for the Proposed Action, about 4.7 percent for Inventory Module 1, and about 5.4 percent for Inventory Module 2.

The emplacement of Inventory Module 1 or 2 would require the same types and annual quantities of hazardous materials as the Proposed Action, as described in Chapter 4, Section 4.1.12.3. These materials would be used for the additional years associated with the emplacement of the module inventory. As with the Proposed Action, no cumulative impact would be likely from the procurement and use of hazardous materials at the repository.

8.2.12.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

A reasonably foreseeable action that could result in waste management impacts that could add to those of the Proposed Action and Inventory Module 1 or 2 would be the selection of the Nevada Test Site as a regional DOE low-level radioactive waste disposal site, as discussed in the Final Waste Management

Table 8-33. Estimated closure phase waste quantities.[a]

Waste type	High thermal load UC[b]	DISP[c]	DPC[d]	Intermediate thermal load UC	DISP	DPC	Low thermal load UC	DISP	DPC
	Proposed Action								
Low-level radioactive (cubic meters)[e]	3,500	2,100	2,500	3,500	2,100	2,500	3,500	2,100	2,500
Hazardous (cubic meters)	630	440	480	630	440	480	630	440	480
Sanitary and industrial solid (cubic meters)	5,300	4,400	4,600	5,400	4,400	4,600	10,000	9,100	9,300
Sanitary sewage (million liters)[f]	87	83	84	87	83	84	200	200	200
Industrial wastewater (million liters)	42	42	42	42	42	42	110	110	110
Demolition debris (cubic meters)	150,000	100,000	120,000	150,000	100,000	120,000	150,000	100,000	120,000
	Inventory Module 1 or 2								
Low-level radioactive (cubic meters)	3,500	2,100	2,500	3,500	2,100	2,500	3,500	2,100	2,500
Hazardous (cubic meters)	630	440	480	630	440	480	630	440	480
Sanitary and industrial solid (cubic meters)	7,700	6,700	6,900	9,100	6,800	8,300	16,000	15,000	15,000
Sanitary sewage (million liters)	150	150	150	150	150	150	350	340	350
Industrial wastewater (million liters)	27	27	27	34	34	34	150	150	150
Demolition debris (cubic meters)	150,000	100,000	120,000	150,000	100,000	120,000	150,000	100,000	120,000

a. Sources: TRW (1999a, page 73); TRW (1999b, pages 6-79 and 6-80).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

Programmatic Environmental Impact Statement (DOE 1997b, page 7-23). The repository (under the uncanistered packaging scenario) which has the largest estimated waste quantities and the other DOE sites that would use Nevada Test Site facilities for disposal under the regional disposal concept would generate about 14,000 cubic meters (490,000 cubic feet) annually (TRW 1999a, page 76; DOE 1997b, pages 7-23 and I-38).

8.2.13 ENVIRONMENTAL JUSTICE

As discussed in Chapter 4, Section 4.1.13, the environmental justice analysis brings together the results of all resource and feature analyses to determine (1) if an activity would have substantial environmental impacts and (2) if those substantial impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. DOE determined that cumulative impacts from Inventory Module 1 or 2 along with those expected from other Federal, non-Federal, and private actions would not produce cumulative adverse impacts to any surrounding populations, which would include minority and low-income populations. Evaluation of subsistence lifestyles and cultural values has confirmed that these factors would not change the conclusion that the absence of high and adverse impacts for the general population means there would be no disproportionately high and adverse

impacts on minority or low-income communities. No substantial impacts were identified; therefore, cumulative impacts from Inventory Module 1 or 2 and other Federal, non-Federal, and private actions would not cause environmental justice concerns.

DOE recognizes that Native American people living in areas near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on free access to the site. Chapter 4, Section 4.1.3.4, discusses these views and beliefs.

8.3 Cumulative Long-Term Impacts in the Proposed Yucca Mountain Repository Vicinity

This section describes results from the long-term cumulative impact analysis that DOE conducted for Inventory Modules 1 and 2 (Section 8.3.1) and for past, present, and reasonably foreseeable future actions at the Nevada Test Site, and past actions at the Beatty low-level radioactive waste site (Section 8.3.2).

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The long-term performance assessment of Inventory Modules 1 and 2 used the same methodology described in Chapter 5 and Appendix I for the Proposed Action to estimate potential human health impacts from radioactive and chemically toxic material releases through waterborne and airborne pathways. Section 8.3.1.1 presents the radioactive and chemically toxic material source terms for Inventory Modules 1 and 2, and Sections 8.3.1.2 and 8.3.1.3 present the results of the analysis for Inventory Modules 1 and 2, respectively.

In addition to long-term human health impacts from radioactive and chemically toxic material releases, the other potential long-term impact identified following repository closure involve biological resources. Though the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the thermal load (expressed in metric tons of heavy metal per acre) would be constant, and, therefore, the ground surface temperature increase would be the same. Thus, long-term biological effects of Module 1 or 2 from heat generated by waste packages that would slightly raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.8 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Source Terms for Inventory Modules 1 and 2

For calculations of long-term performance impacts, the radioactive material inventory of individual waste packages for commercial spent nuclear fuel, high-level radioactive waste, and DOE spent nuclear fuel under Inventory Modules 1 and 2 would be identical to the radioactive material inventory under the Proposed Action for the same waste categories. Inventory Module 2 includes an additional waste category for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. This category includes a different category of waste package with its own radioactive material inventory. This waste would be emplaced in 608 "naval spent nuclear fuel long waste" packages (TRW 1999c, page 6-9), of which approximately 55 would contain waste from naval reactors and the remainder would contain waste from DOE and commercial reactors. The inventory used for each modeled waste package is an averaged radioactive material inventory of each waste category (commercial spent nuclear fuel, DOE spent nuclear fuel, high-level radioactive waste, and Greater-Than-Class-C and Special-Performance-Assessment-Required wastes). More waste packages would be used for Inventory Modules 1 and 2 than for the Proposed Action to accommodate the expanded inventories. Table 8-34 lists the number of waste packages used in long-term performance assessment calculations for the Proposed Action and Modules 1 and 2.

Table 8-34. Number of waste packages used in long-term performance assessment calculations.[a]

Inventory	Commercial SNF[b]	HLW[c]	DOE SNF	GTCC and SPAR[d]	Total
Proposed Action	7,760	1,663	2,546	0	11,969
Inventory Module 1	12,933	4,456	4,341	0	21,730
Inventory Module 2	12,933	4,456	4,341	1,642	23,372

a. The number of waste packages represented in RIP model simulations would not exactly match the number of actual waste packages. Refer to Appendix I, Section I.3 for a detailed description of waste package abstraction.
b. SNF = spent nuclear fuel.
c. HLW = high-level radioactive waste.
d. GTCC = Greater-Than-Class-C, SPAR = Special-Performance-Assessment-Required.

As listed in Table 8-34, Inventory Module 2 differs from Inventory Module 1 only by the addition of 1,642 Greater-than-Class-C and Special-Performance-Assessment-Required waste packages [the abstracted number of packages for this category of waste (1,642) differs substantially from the actual number (608), but the total radionuclide inventory is identical; the difference concerns only the number of packages modeled for waste package degradation calculations in RIP and is not expected to impact results appreciably]. Table 8-35 lists the inventory of the Greater-than-Class-C and Special-Performance-Assessment-Required waste packages under Inventory Module 2.

Table 8-35. Average radionuclide inventory (curies) per waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes used in performance assessment calculations under Inventory Module 2.

Isotope	Inventory
Carbon-14	38
Iodine-129	1.2×10^{-8}
Neptunium-237	5.2×10^{-8}
Protactinium-231	7.00×10^{-8}
Plutonium-239	48
Plutonium-242	4.0×10^{-6}
Selenium-79	1.0×10^{-6}
Technetium-99	2.6
Uranium-234	6.2×10^{-7}

Table 8-36 lists the total inventory of elemental uranium (that is, all isotopes of uranium) for consideration as a chemically toxic material for the Proposed Action and for Inventory Module 1 or 2. The total uranium inventory for Module 1 or 2 would be about 70 percent greater than for the Proposed Action.

Table 8-36. Total inventory (kilograms)[a] of uranium in the repository under the Proposed Action and Inventory Module 1 or 2.[b]

Inventory	Commercial SNF[c]	HLW[d]	DOE SNF	Total
Proposed Action	63,000,000	4,700,000	2,300,000	70,000,000
Inventory Module 1 or 2[e]	105,000,000	12,600,000	2,500,000	120,000,000

a. To convert kilograms to pounds, multiply by 2.2046.
b. The uranium content in high-level radioactive waste was set to the MTHM equivalent for this analysis, even though much of the uranium would have been removed during reprocessing operations.
c. SNF = spent nuclear fuel.
d. HLW = high-level radioactive waste.
e. Inventory Modules 1 and 2 would have the same total uranium inventory because Greater-Than-Class-C and Special-Performance-Assessment-Required wastes, (the only additional inventory in Module 2 over Module 1) does not contain a substantial quantity of uranium.

Table 8-37 lists the total chromium inventory for the Proposed Action and Inventory Modules 1 and 2 from waste packages. The analysis used this inventory to calculate the potential impacts to human health from chemically toxic chromium in the waste package materials and in the pressurized- and boiling-water reactor fuel assemblies. The inventory does not include the chromium content of stainless steel that would be stored with the waste in the waste packages. Further information on the chromium inventory is provided in Chapter 5 and in more detail in Appendix I.

Table 8-37. Total chromium in the Proposed Action and Inventory Modules 1 and 2 (kilograms).[a,b]

Inventory	Commercial SNF[c]	HLW[d]	DOE SNF	GTCC and SPAR[e]	Total
Proposed Action	11,000,000	2,100,000	380,000	0	14,000,000
Inventory Module 1	18,000,000	4,400,000	400,000	0	23,000,000
Inventory Module 2	18,000,000	4,400,000	400,000	730,000	24,000,000

a. To convert kilograms to pounds, multiply by 2.2046.
b. Totals might differ from sums due to rounding.
c. SNF = spent nuclear fuel.
d. HLW = high-level radioactive waste.
e. GTCC = Greater-Than-Class-C waste; SPAR = Special-Performance-Assessment-Required waste.

The only radionuclide that would have a relatively large inventory and a potential for gas transport is carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be likely to dissolve in groundwater rather than migrate as a gas. After the carbon-14 escaped from the waste package, it could flow through the fractured and porous rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in gas in the space (or gap) between the fuel and the cladding around the fuel (Oversby 1987, page 92). The gaseous inventory consists of 0.234 curie of carbon-14 per commercial spent nuclear fuel waste package. The additional carbon-14 activity associated with Inventory Module 2, in relation to Module 1, would be the core shrouds. The carbon-14 would result from neutron irradiation of the core shroud metal. The carbon-14 would be unlikely to be present as gaseous carbon dioxide that could be released to the environment (see Table 8-38).

Table 8-38. Total carbon-14 in the repository for the Proposed Action and Inventory Modules 1 and 2 (curies).[a]

Inventory	Solid[b]	Gaseous[c]	Total
Proposed Action	92,000	1,800	93,000
Inventory Module 1	150,000	3,200	160,000
Inventory Module 2	240,000	3,200	240,000

a. Totals might differ from sums due to rounding.
b. Impacts of carbon-14 in solid form are addressed as waterborne radioactive material impacts.
c. Based on 0.234 curies of carbon-14 per commercial spent nuclear fuel waste package.

8.3.1.2 Impacts for Inventory Module 1

The analysis included human-health impacts from Inventory Module 1 for radioactive materials and chemically toxic materials, as discussed in the following sections.

8.3.1.2.1 *Waterborne Radioactive Material Impacts*

The analysis used the modeling methods described for the Proposed Action in Chapter 5 (and in greater detail in Appendix I) to calculate the impacts for a maximally exposed individual and population resulting from groundwater releases of radioactive material for 10,000 years and 1 million years following repository closure for Inventory Module 1.

8.3.1.2.1.1 High Thermal Load Scenario. Table 8-39 lists the estimated impacts for a maximally exposed individual for the high thermal load scenario under the Proposed Action and Inventory Module 1. In general, the impacts from Module 1 would be higher by a factor ranging from 3 to 5 times the values calculated for this scenario under the Proposed Action. This increase is higher than the ratio of inventories between Module 1 and the Proposed Action. Reasons for the higher impacts include different

Table 8-39. Impacts for a maximally exposed individual from groundwater releases of radionuclides during 10,000 years after repository closure for the high thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Maximally exposed individual	Peak dose rate[b] (millirem/year)	Probability of a LCF[c]	Peak dose rate[b] (millirem/year)	Probability of a LCF[c]
Proposed Action	At 5 kilometers[d]	0.32	1.1×10^{-5}	1.3	4.4×10^{-5}
	At 20 kilometers	0.22	7.6×10^{-6}	0.58	2.0×10^{-5}
	At 30 kilometers	0.12	4.2×10^{-6}	0.28	1.0×10^{-5}
	At 80 kilometers	0.03	1.1×10^{-6}	0.0029	1.0×10^{-7}
Inventory Module 1	At 5 kilometers	1.6	5.6×10^{-5}	5.5	1.9×10^{-4}
	At 20 kilometers	1.1	3.7×10^{-5}	2.4	8.2×10^{-5}
	At 30 kilometers	0.48	1.7×10^{-5}	0.77	2.7×10^{-5}
	At 80 kilometers	0.15	5.3×10^{-6}	0.012	3.7×10^{-7}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
c. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).
d. To convert kilometers to miles, multiply by 0.62137.

water percolation fluxes in different areas of the repository and the percolation flux impacts on the dissolution and transport of radionuclides. Appendix I, Section I.5.2, discusses these effects further.

Table 8-40 lists the impacts to the population during the first 10,000 years after repository closure for both the Proposed Action and Inventory Module 1 for the high thermal load scenario. The population impacts would be higher than the impacts for the Proposed Action under the same thermal load scenario. For example, the population dose in the 70-year period of maximum impacts would be about 5 times greater for Module 1 than for the Proposed Action at the 95th-percentile level and the same 70-year period. However, the 10,000-year integrated doses for the 95th-percentile level would be only about 2 times greater for Module 1 than for the Proposed Action.

Table 8-40. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the high thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Case	Population dose (person-rem)	Population LCFs[b]	Population dose (person-rem)	Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.015	7.5×10^{-6}	0.035	1.8×10^{-5}
	Integrated over 10,000 years	0.37	1.8×10^{-4}	1.2	5.8×10^{-4}
Inventory Module 1	Peak 70-year lifetime	0.11	5.5×10^{-5}	0.18	9.0×10^{-5}
	Integrated over 10,000 years	2.6	1.3×10^{-3}	2.9	1.4×10^{-3}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).

The range of the increase in population impacts for Inventory Module 1 compared to the Proposed Action listed in Table 8-40 differs from the range of increase in impacts for a maximally exposed individual under Module 1 listed in Table 8-39. The major factor in the difference is the amount of contaminated groundwater associated with the Proposed Action and Module 1. The Proposed Action calculations use 27,000 cubic meters (22 acre-feet) annually in the flow tubes when calculating population dose (Appendix I, Section I.4.5.3). This amount of water is diluted in 19,000,000 cubic meters (15,400 acre-feet) of water for regional population use. The calculations for increased repository size under Module 1 use 36,000 cubic meters (29 acre-feet) of water annually in the flow tubes. This difference in water use

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 100 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed.*

The performance results reported in this EIS are highly skewed. In this context, skewed indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, it dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are often above the 90th-percentile and occasionally above the 95th-percentile.

increases the population dose by about a factor of 2 for Inventory Module 1 over that calculated for the Proposed Action.

Table 8-41 lists the peak dose rate and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the high thermal load scenario. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-40, with the impacts for Module 1 ranging from 2 to 4 times greater than those for the Proposed Action.

Table 8-41. Impacts for a maximally exposed individual from groundwater releases of radionuclides for 1 million years after repository closure for the high thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Maximally exposed individual	Peak dose rate (millirem/year)	Time of peak (years)	Peak dose rate (millirem/year)	Time of peak (years)
Proposed Action	At 5 kilometers[b]	1,400	296,000	9,100	320,000
	At 20 kilometers	260	336,000	1,400	364,000
	At 30 kilometers	150	418,000	820	416,000
	At 80 kilometers	54	818,000	190	716,000
Inventory Module 1	At 5 kilometers	5,300	792,000	39,000	698,000
	At 20 kilometers	930	336,000	5,600	804,000
	At 30 kilometers	480	392,000	1,700	752,000
	At 80 kilometers	160	328,000	610	742,000

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. To convert kilometers to miles, multiply by 0.62137.

Table 8-42 lists peak radionuclide and alpha particle concentrations in water at four locations for the high thermal load scenario under the Proposed Action and Inventory Module 1. The peak concentrations would be for 10,000 years after repository closure. The concentrations and drinking water doses would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-40, with the results for Module 1 being commensurately greater than those for the Proposed Action. The gross alpha concentration represents the amount of alpha particle radioactivity (alpha particles are positively charged particles emitted by certain radioactive material, made up of two neutrons and two protons). The analysis derived the consequences at each distance from a different set of 100 simulations. Therefore, fluctuations in the relative concentration of specific nuclides could occur at different distances. The radionuclides that would contribute the most to individual dose over 10,000 years would be iodine-129, technetium-99, and carbon-14. The analysis based the annual drinking water doses listed in Table 8-42 (and below in Tables 8-46 and 8-50) on the assumption that an individual drinks an average of 2 liters (0.5 gallon) of water a day.

Table 8-42. Radionuclide concentrations (picocuries per liter) in water at four locations for 10,000 years after repository closure for the high thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean				95th-percentile			
Inventory	Radionuclide	5 km[b]	20 km	30 km	80 km	5 km	20 km	30 km	80 km
Proposed Action	Carbon-14	2.1	1.1	6.4×10^{-1}	1.8×10^{-3}	8.2	1.8	3.1	2.7×10^{-2}
	Iodine-129	1.3×10^{-1}	7.0×10^{-2}	4.1×10^{-2}	1.0×10^{-4}	5.7×10^{-1}	1.2×10^{-1}	2.0×10^{-1}	2.0×10^{-3}
	Neptunium-237	6.4×10^{-4}	2.3×10^{-8}	6.1×10^{-15}	5.6×10^{-24}	6.5×10^{-4}	1.3×10^{-17}	1.3×10^{-23}	4.2×10^{-24}
	Protactinium-231	2.9×10^{-12}	4.7×10^{-26}	4.7×10^{-26}	2.4×10^{-26}	2.0×10^{-24}	2.0×10^{-24}	1.3×10^{-26}	1.3×10^{-26}
	Plutonium-239	5.7×10^{-5}	5.6×10^{-9}	4.8×10^{-10}	1.3×10^{-13}	1.8×10^{-9}	2.4×10^{-11}	8.1×10^{-10}	2.1×10^{-17}
	Plutonium-242	3.5×10^{-7}	2.9×10^{-11}	3.1×10^{-12}	8.9×10^{-16}	1.0×10^{-11}	7.8×10^{-14}	4.5×10^{-12}	1.5×10^{-19}
	Selenium-79	3.8×10^{-1}	8.2×10^{-4}	2.4×10^{-6}	1.4×10^{-21}	1.7	1.4×10^{-18}	6.8×10^{-19}	3.2×10^{-21}
	Technetium-99	4.5×10^{1}	3.0×10^{1}	1.0×10^{1}	3.3×10^{-2}	3.9×10^{2}	8.4×10^{1}	1.3×10^{2}	8.3×10^{-1}
	Uranium-234	8.8×10^{-5}	9.0×10^{-10}	1.2×10^{-16}	2.9×10^{-23}	8.3×10^{-5}	4.4×10^{-23}	3.7×10^{-23}	3.7×10^{-23}
	Drinking water dose (millirem/ year)	8.1×10^{-2}	4.8×10^{-2}	2.0×10^{-2}	5.9×10^{-5}	5.4×10^{-1}	1.2×10^{-1}	1.8×10^{-1}	1.3×10^{-3}
	Gross alpha	7.0×10^{-4}	2.9×10^{-8}	4.8×10^{-10}	1.3×10^{-13}	6.5×10^{-4}	2.4×10^{-11}	8.1×10^{-10}	2.1×10^{-17}
Inventory Module 1	Carbon-14	1.0×10^{1}	6.3	2.5	3.9×10^{-1}	2.9×10^{1}	6.9×10^{1}	3.2	1.3×10^{-1}
	Iodine-129	7.2×10^{-1}	4.4×10^{-1}	1.6×10^{-1}	2.8×10^{-2}	1.8	4.9	2.4×10^{-1}	8.9×10^{-3}
	Neptunium-237	1.8×10^{-3}	1.8×10^{-7}	4.8×10^{-14}	7.6×10^{-23}	1.9×10^{-3}	2.5×10^{-24}	1.3×10^{-21}	4.2×10^{-24}
	Protactinium-231	1.8×10^{-13}	5.9×10^{-26}	5.9×10^{-26}	6.0×10^{-26}	2.6×10^{-24}	7.7×10^{-27}	2.5×10^{-24}	1.3×10^{-26}
	Plutonium-239	3.9×10^{-4}	1.7×10^{-7}	1.2×10^{-9}	2.4×10^{-12}	3.2×10^{-10}	3.0×10^{-11}	4.0×10^{-11}	2.8×10^{-16}
	Plutonium-242	2.4×10^{-6}	1.1×10^{-9}	7.2×10^{-12}	1.5×10^{-14}	8.8×10^{-13}	1.7×10^{-13}	8.8×10^{-14}	1.7×10^{-18}
	Selenium-79	1.6	6.5×10^{-3}	2.3×10^{-5}	6.9×10^{-21}	3.2	3.0×10^{-20}	2.1×10^{-18}	1.2×10^{-19}
	Technetium-99	2.0×10^{2}	1.3×10^{2}	5.4×10^{1}	1.7×10^{1}	1.3×10^{3}	4.6×10^{2}	1.8×10^{2}	1.5
	Uranium-234	1.8×10^{-4}	2.5×10^{-9}	4.7×10^{-16}	8.3×10^{-23}	4.3×10^{-4}	2.2×10^{-23}	5.7×10^{-23}	3.7×10^{-23}
	Drinking water dose (millirem/year)	3.9×10^{-1}	2.4×10^{-1}	9.3×10^{-2}	2.4×10^{-2}	1.8	1.6	2.5×10^{-1}	3.6×10^{-3}
	Gross alpha	2.2×10^{-3}	3.5×10^{-7}	1.2×10^{-9}	2.4×10^{-12}	1.9×10^{-3}	3.1×10^{-11}	4.0×10^{-11}	2.8×10^{-16}

a. The concentrations for the mean and 95th-percentile consequences are the concentrations that yielded the mean and 95th-percentile doses.

b. To convert kilometers (km) to miles, multiply by 0.62137.

8.3.1.2.1.2 Intermediate Thermal Load Scenario. Table 8-43 lists the estimated impacts to a maximally exposed individual from groundwater releases of radionuclides during the first 10,000 years after repository closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1. The impacts for Module 1 would generally be a factor ranging from 2 to 11 higher than those calculated for the Proposed Action. The increase is higher than the ratio of inventories between Module 1 and the Proposed Action. Reasons for the higher impacts include different water percolation fluxes in different regions of the repository and the percolation flux impacts on the dissolution and transport of radionuclides. Appendix I, Section I.5.2, discusses these effects further.

Table 8-44 lists population impacts from groundwater releases of radionuclides during the first 10,000 years after repository closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1. The population impacts for Inventory Module 1 would be higher than those for the Proposed Action under the same thermal load scenario. For example, the population dose in the 70-year period of maximum impacts would be about 5 times greater for Module 1 than for the Proposed Action at the 95th-percentile level. In addition, the 10,000-year integrated dose for the 95th-percentile level would be about 4 times greater for Module 1 than for the Proposed Action. Again, as for the high thermal load scenario, the range of increase in population dose differs from the range of increase for the maximally exposed individual dose because of the difference in the amount of contaminated groundwater (see Section 8.3.1.2.1.1).

Table 8-43. Impacts for a maximally exposed individual from groundwater releases of radionuclides during the 10,000 years after repository closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1.[a]

Inventory	Maximally exposed individual	Mean		95th-percentile	
		Peak dose rate[b] (millirem/year)	Probability of a LCF[c]	Peak dose rate[b] (millirem/year)	Probability of a LCF[c]
Proposed Action	At 5 kilometers[d]	0.14	4.9×10^{-6}	1.1	3.9×10^{-5}
	At 20 kilometers	0.13	4.5×10^{-6}	0.58	2.0×10^{-5}
	At 30 kilometers	0.046	1.6×10^{-6}	0.11	3.9×10^{-6}
	At 80 kilometers	0.0029	1.0×10^{-7}	0.0019	6.6×10^{-8}
Inventory Module 1	At 5 kilometers	0.74	2.6×10^{-5}	3.4	1.2×10^{-4}
	At 20 kilometers	0.44	1.6×10^{-5}	1.5	5.1×10^{-5}
	At 30 kilometers	0.19	6.5×10^{-6}	0.34	1.2×10^{-5}
	At 80 kilometers	0.03	1.1×10^{-6}	0.0034	1.2×10^{-7}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
c. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).
d. To convert kilometers to miles, multiply by 0.62137.

Table 8-44. Population impacts from groundwater releases of radionuclides during the 10,000 years after repository closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1.[a]

Inventory	Case	Mean		95th-percentile	
		Population dose (person-rem)	Population LCFs[b]	Population dose (person-rem)	Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.007	3.3×10^{-6}	0.017	8.3×10^{-6}
	Integrated over 10,000 years	0.13	6.7×10^{-5}	0.36	1.8×10^{-4}
Inventory Module 1	Peak 70-year lifetime	0.043	2.2×10^{-5}	0.080	4.0×10^{-5}
	Integrated over 10,000 years	1.0	5.2×10^{-4}	1.4	7.2×10^{-4}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).

Table 8-45 lists the peak dose rate and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the intermediate thermal load scenario. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-43, with the impacts for Module 1 being about 2 to 5 times greater than those for the Proposed Action.

Table 8-46 lists peak radionuclide and alpha particle concentrations in water at four locations for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1. These concentrations would occur 10,000 years after repository closure. The concentrations and the drinking water doses would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-43, with the results for Module 1 being commensurately greater than those for the Proposed Action. The analysis derived the consequences at each distance from a different set of 100 simulations. Therefore, fluctuations in the relative concentration of specific nuclides could occur at different distances. The radionuclides that would contribute the most to individual dose in 10,000 years would be iodine-129, technetium-99, and carbon-14.

Table 8-45. Impacts for a maximally exposed individual from groundwater releases of radionuclides during the 1 million years after repository closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Maximally exposed individual	Peak dose rate (millirem/year)	Time of peak (years)	Peak dose rate (millirem/year)	Time of peak (years)
Proposed Action	At 5 kilometers[b]	470	296,000	2,800	320,000
	At 20 kilometers	170	804,000	900	712,000
	At 30 kilometers	91	418,000	500	932,000
	At 80 kilometers	32	872,000	120	702,000
Inventory Module 1	At 5 kilometers	2,300	698,000	15,000	342,000
	At 20 kilometers	400	336,000	2,500	712,000
	At 30 kilometers	240	422,000	1,300	752,000
	At 80 kilometers	110	334,000	330	712,000

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. To convert kilometers to miles, multiply by 0.62137.

Table 8-46. Radionuclide concentrations (picocuries per liter) in water and doses at four locations for the 10,000 years after closure for the intermediate thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean				95th-percentile			
Inventory	Radionuclide	5 km[b]	20 km	30 km	80 km	5 km	20 km	30 km	80 km
Proposed Action	Carbon-14	1.2	1.1	4.4×10^{-1}	1.6×10^{-2}	9.6	5.9	6.7×10^{-1}	4.1×10^{-2}
	Iodine-129	8.0×10^{-2}	5.5×10^{-2}	2.9×10^{-2}	1.1×10^{-3}	7.2×10^{-1}	4.3×10^{-1}	4.8×10^{-2}	2.8×10^{-3}
	Neptunium-237	9.1×10^-[illegible]	8.0×10^{-9}	7.5×10^{-16}	2.2×10^{-23}	1.3×10^{-6}	4.2×10^{-14}	5.1×10^{-22}	2.4×10^{-24}
	Protactinium-231	1.5×10^{-14}	5.0×10^{-26}	3.8×10^{-26}	3.8×10^{-26}	1.2×10^{-26}	1.6×10^{-24}	1.6×10^{-24}	7.6×10^{-27}
	Plutonium-239	6.9×10^{-6}	3.2×10^{-9}	2.4×10^{-10}	7.0×10^{-13}	6.3×10^{-10}	3.0×10^{-10}	2.7×10^{-12}	2.5×10^{-11}
	Plutonium-242	4.8×10^{-8}	2.2×10^{-11}	1.4×10^{-12}	4.8×10^{-15}	3.5×10^{-12}	1.8×10^{-12}	9.3×10^{-15}	1.7×10^{-13}
	Selenium-79	9.4×10^{-2}	4.3×10^{-4}	2.6×10^{-6}	2.0×10^{-21}	5.0×10^{-1}	1.8×10^{-18}	1.3×10^{-18}	3.1×10^{-21}
	Technetium-99	2.1×10^{1}	1.7×10^{1}	4.5	3.7×10^{-1}	4.3×10^{2}	1.8×10^{2}	1.7×10^{1}	1.1
	Uranium-234	1.9×10^{-5}	4.0×10^{-11}	7.8×10^{-17}	2.9×10^{-23}	1.3×10^{-7}	6.3×10^{-16}	2.9×10^{-23}	2.1×10^{-23}
	Drinking water dose (millirem/ year)	4.1×10^{-2}	3.1×10^{-2}	1.1×10^{-2}	6.5×10^{-4}	6.2×10^{-1}	2.9×10^{-1}	2.9×10^{-2}	1.8×10^-[illegible]
	Gross alpha	9.8×10^-[illegible]	1.1×10^{-8}	2.4×10^{-10}	7.0×10^{-13}	1.3×10^{-6}	3.1×10^{-10}	2.7×10^{-12}	2.5×10^{-11}
Inventory Module 1	Carbon-14	4.7	3.7	1.4	1.1×10^{-1}	2.7×10^{1}	4.3×10^{1}	1.8	2.7×10^{-2}
	Iodine-129	3.1×10^{-1}	2.6×10^{-1}	9.9×10^{-2}	7.8×10^{-3}	1.9	3.1	1.3×10^{-1}	2.0×10^{-3}
	Neptunium-237	1.6×10^{-3}	5.1×10^{-8}	1.5×10^{-14}	9.3×10^{-23}	3.4×10^{-6}	8.6×10^{-24}	9.9×10^{-22}	3.4×10^{-24}
	Protactinium-231	2.2×10^{-12}	3.0×10^{-25}	7.4×10^{-26}	7.7×10^{-26}	2.7×10^{-23}	1.1×10^{-26}	3.3×10^{-24}	1.1×10^{-26}
	Plutonium-239	1.8×10^{-4}	7.1×10^{-8}	1.9×10^{-9}	1.2×10^{-12}	1.5×10^{-9}	7.4×10^{-12}	9.2×10^{-12}	3.0×10^{-12}
	Plutonium-242	1.1×10^{-6}	4.5×10^{-10}	8.7×10^{-12}	8.0×10^{-15}	8.4×10^{-12}	4.1×10^{-14}	2.5×10^{-14}	1.7×10^{-14}
	Selenium-79	1.2	2.5×10^{-3}	2.0×10^{-5}	1.0×10^{-20}	4.6	2.8×10^{-17}	3.2×10^{-18}	3.4×10^{-20}
	Technetium-99	1.0×10^[illegible]	4.7×10^{1}	1.5×10^{1}	3.1	1.3×10^{3}	2.9×10^{2}	7.5×10^{1}	9.0×10^{-1}
	Uranium-234	1.1×10^{-4}	8.1×10^{-10}	4.8×10^{-16}	6.1×10^{-23}	5.5×10^{-7}	3.0×10^{-23}	7.1×10^{-23}	3.0×10^{-23}
	Drinking water dose (millirem/year)	1.9×10^{-1}	1.1×10^{-1}	3.8×10^{-2}	5.0×10^{-3}	1.8	9.9×10^{-1}	1.1×10^{-1}	1.4×10^{-3}

a. The concentrations for the mean and 95th-percentile consequences are those that would yield the mean and 95th-percentile doses.
b. To convert kilometers (km) to miles, multiply by 0.62137.

8.3.1.2.1.3 Low Thermal Load Scenario. Table 8-47 lists the estimated impacts to a maximally exposed individual from groundwater releases of radionuclides during the first 10,000 years after repository closure for the low thermal load scenario under the Proposed Action and Inventory Module 1. The impacts for Module 1 would be nearly the same to 3 times greater compared to those calculated for this scenario under the Proposed Action.

Table 8-47. Impacts for a maximally exposed individual from groundwater releases of radionuclides during the 10,000 years after repository closure for the low thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Maximally exposed individual	Peak dose rate[b] (millirem/year)	Probability of a LCF[c]	Peak dose rate[b] (millirem/year)	Probability of a LCF[c]
Proposed Action	At 5 kilometers[d]	0.13	4.7×10^{-6}	0.16	5.6×10^{-6}
	At 20 kilometers	0.059	2.1×10^{-6}	0.061	2.1×10^{-6}
	At 30 kilometers	0.040	1.4×10^{-6}	0.023	8.1×10^{-7}
	At 80 kilometers	0.00053	1.9×10^{-8}	0.0019	6.6×10^{-8}
Inventory Module 1	At 5 kilometers	0.21	7.5×10^{-6}	0.25	8.8×10^{-6}
	At 20 kilometers	0.12	4.1×10^{-6}	0.12	4.2×10^{-6}
	At 30 kilometers	0.086	3.0×10^{-6}	0.069	2.4×10^{-6}
	At 80 kilometers	0.00066	2.3×10^{-8}	0.0041	1.4×10^{-7}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. All peaks occur at or near 10,000 years, indicating that the dose rate would still be rising at the end of the simulation period.
c. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals and expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).
d. To convert kilometers to miles, multiply by 0.62137.

Table 8-48 lists population impacts from groundwater releases of radionuclides during the first 10,000 years after repository closure for the low thermal load scenario under the Proposed Action and Inventory Module 1. The population impacts for Module 1 would be higher than those for the Proposed Action under the same thermal load scenario. For example, the population dose in the 70-year period of maximum impacts would be about 6 times greater for Module 1 than for the Proposed Action at the 95th-percentile level. In addition, the 10,000-year integrated dose for the 95th-percentile level would be about 7 times greater for Module 1 than for the Proposed Action. Again, as for the high thermal load scenario, the range of increase in population dose differs from the range of increase for the maximally exposed individual dose because of the difference in the amount of contaminated groundwater (see Section 8.3.1.2.1.1).

Table 8-48. Population impacts from groundwater releases of radionuclides during the 10,000 years after repository closure for the low thermal load scenario under the Proposed Action and Inventory Module 1.[a]

		Mean		95th-percentile	
Inventory	Case	Population dose (person-rem)	Population LCFs[b]	Population dose (person-rem)	Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.001	5.3×10^{-6}	0.0062	3.1×10^{-6}
	Integrated over 10,000 years	0.27	1.3×10^{-4}	0.12	6.0×10^{-5}
Inventory Module 1	Peak 70-year lifetime	0.048	2.4×10^{-5}	0.039	1.9×10^{-5}
	Integrated over 10,000 years	1.0	5.2×10^{-4}	0.83	4.2×10^{-4}

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals and expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (NCRP 1993a, page 31).

Table 8-49 lists the peak dose rate and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the low thermal load scenario. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-23, with the impacts for Module 1 being approximately the same to 3 times greater than those for the Proposed Action.

Table 8-49. Impacts for a maximally exposed individual from groundwater releases of radionuclides during 1 million years after repository closure for the low thermal load scenario under the Proposed Action and Inventory Module 1.[a]

Inventory	Maximally exposed individual	Mean: Peak dose rate (millirem/year)	Mean: Time of peak (years)	95th-percentile: Peak dose rate (millirem/year)	95th-percentile: Time of peak (years)
Proposed Action	At 5 kilometers[b]	630	296,000	3,600	320,000
	At 20 kilometers	160	804,000	860	334,000
	At 30 kilometers	73	400,000	360	308,000
	At 80 kilometers	44	824,000	160	726,000
Inventory Module 1	At 5 kilometers	1,100	296,000	9,100	342,000
	At 20 kilometers	200	336,000	1,200	804,000
	At 30 kilometers	130	398,000	680	308,000
	At 80 kilometers	43	946,000	170	746,000

a. Based on 100 simulations of total system performance for each location, using random samples of uncertain parameters.
b. To convert kilometers to miles, multiply by 0.62137.

Table 8-50 lists peak radionuclide and alpha particle concentrations in water at four locations for the low thermal load scenario under the Proposed Action and Inventory Module 1. The peak concentrations would be for 10,000 years after repository closure. The concentrations and the drinking water doses

Table 8-50. Radionuclide concentrations (picocuries per liter) in water and doses at four locations for 10,000 years after closure for the low thermal load scenario under the Proposed Action and Inventory Module 1.

Inventory	Radionuclide	Mean[a]: 5 km[b]	Mean: 20 km	Mean: 30 km	Mean: 80 km	95th-percentile: 5 km	95th-percentile: 20 km	95th-percentile: 30 km	95th-percentile: 80 km
Proposed Action	Carbon-14	1.6	7.9×10^{-1}	4.0×10^{-1}	6.7×10^{-3}	5.6	5.9	2.1×10^{-1}	3.1×10^{-2}
	Iodine-129	1.0×10^{-1}	5.0×10^{-2}	2.3×10^{-2}	4.8×10^{-4}	4.0×10^{-1}	1.5×10^{-1}	1.8×10^{-25}	2.4×10^{-3}
	Neptunium-237	7.3×10^{-4}	9.3×10^{-12}	2.2×10^{-16}	9.1×10^{-23}	1.4×10^{-6}	4.0×10^{-12}	7.1×10^{-25}	7.1×10^{-25}
	Protactinium-231	1.4×10^{-16}	2.6×10^{-24}	7.8×10^{-26}	7.9×10^{-26}	1.6×10^{-16}	7.7×10^{-27}	2.2×10^{-27}	2.2×10^{-27}
	Plutonium-239	9.4×10^{-5}	2.4×10^{-9}	1.1×10^{-9}	6.5×10^{-13}	2.5×10^{-13}	7.7×10^{-16}	4.0×10^{-14}	7.7×10^{-13}
	Plutonium-242	6.9×10^{-7}	1.6×10^{-11}	5.5×10^{-12}	4.5×10^{-15}	3.2×10^{-16}	4.3×10^{-18}	2.8×10^{-16}	5.5×10^{-15}
	Selenium-79	2.7×10^{-1}	4.4×10^{-6}	8.9×10^{-12}	7.8×10^{-22}	3.2	1.8×10^{-7}	1.7×10^{-21}	1.6×10^{-20}
	Technetium-99	1.7×10^{1}	7.3	4.5	7.2×10^{-2}	1.9	1.4×10^{1}	6.3	3.4×10^{-1}
	Uranium-234	3.1×10^{-6}	1.5×10^{-12}	4.1×10^{-16}	1.5×10^{-23}	2.0×10^{-7}	6.7×10^{-11}	6.2×10^{-24}	6.2×10^{-24}
	Drinking water dose (millirem/year)	4.4×10^{-2}	1.9×10^{-2}	1.0×10^{-2}	1.8×10^{-4}	9.5×10^{-2}	5.3×10^{-2}	7.0×10^{-3}	9.1×10^{-4}
	Gross alpha	8.2×10^{-4}	1.4×10^{-9}	1.1×10^{-9}	6.6×10^{-13}	1.4×10^{-6}	4.0×10^{-12}	4.0×10^{-14}	7.7×10^{-13}
Inventory Module 1	Carbon-14	2.7×10^{0}	1.4×10^{0}	8.9×10^{-1}	1.1×10^{-2}	6.4×10^{0}	4.2	4.9×10^{-1}	5.6×10^{-2}
	Iodine-129	1.7×10^{-1}	1.0×10^{-1}	6.3×10^{-2}	7.2×10^{-4}	4.6×10^{-1}	2.9×10^{-1}	3.6×10^{-2}	2.9×10^{-3}
	Neptunium-237	1.7×10^{-3}	5.3×10^{-12}	8.5×10^{-17}	1.0×10^{-21}	1.4×10^{-9}	6.0×10^{-11}	1.7×10^{-24}	1.7×10^{-24}
	Protactinium-231	8.2×10^{-18}	8.6×10^{-25}	8.0×10^{-26}	8.3×10^{-26}	5.4×10^{-27}	5.4×10^{-27}	5.4×10^{-27}	5.4×10^{-27}
	Plutonium-239	6.1×10^{-4}	1.5×10^{-8}	1.0×10^{-9}	2.0×10^{-12}	7.8×10^{-16}	9.3×10^{-14}	9.8×10^{-14}	5.1×10^{-16}
	Plutonium-242	3.4×10^{-6}	1.2×10^{-11}	4.6×10^{-12}	1.4×10^{-14}	4.0×10^{-18}	6.3×10^{-16}	6.9×10^{-16}	3.3×10^{-18}
	Selenium-79	4.8×10^{-1}	2.2×10^{-4}	7.5×10^{-11}	1.5×10^{-21}	5.6×10^{0}	1.2×10^{-18}	2.1×10^{-21}	3.6×10^{-21}
	Technetium-99	1.5×10^{1}	9.5×10^{0}	8.9×10^{0}	1.6×10^{-1}	2.0×10^{1}	1.3×10^{1}	1.4×10^{1}	3.2×10^{-1}
	Uranium-234	9.1×10^{-6}	3.6×10^{-12}	8.3×10^{-16}	2.7×10^{-23}	6.3×10^{-8}	1.5×10^{-23}	1.5×10^{-23}	1.5×10^{-23}
	Drinking water dose (millirem/year)	6.1×10^{-2}	3.3×10^{-2}	2.3×10^{-2}	3.3×10^{-4}	1.3×10^{-1}	7.9×10^{-2}	2.3×10^{-2}	1.0×10^{-3}
	Gross alpha	2.3×10^{-3}	1.5×10^{-8}	1.0×10^{-9}	2.0×10^{-12}	1.4×10^{-9}	6.0×10^{-11}	9.9×10^{-14}	5.1×10^{-16}

a. The concentrations for the mean and 95th-percentile consequences would be those that yielded the mean and 95th-percentile doses.
b. To convert kilometers (km) to miles, multiply by 0.62137.

would follow the same pattern as for the first 10,000 years after repository closure listed in Table 8-47, with the results for Module 1 being commensurately greater than those for the Proposed Action. The analysis derived the consequences at each distance from a different set of 100 simulations. Therefore, fluctuations in the relative concentration of specific nuclides could occur at different distances. The radionuclides that would contribute the most to individual dose in 10,000 years would be iodine-129, technetium-99, and carbon-14.

8.3.1.2.2 *Waterborne Chemically Toxic Material Impacts*

The Proposed Action impacts described in Chapter 5, Section 5.6.3, for uranium would be about 100,000 times smaller than a threshold concentration based on the reference dose for elemental uranium of 0.003 milligram per kilogram per day (EPA 1999d, all). The Environmental Protection Agency has not established a Maximum Contaminant Level Goal for elemental uranium. The 70-percent increase in uranium inventory for Inventory Module 1 (see Table 8-36) would still result in impacts that were much smaller than the threshold concentration. Therefore, uranium would not present a substantial impact as a chemically toxic material under Module 1.

Using the modeling methods described in Chapter 5 (and in greater detail in Appendix I), DOE analyzed the impacts of chromium as a chemically toxic material for Inventory Module 1. The analysis included all four receptor locations under all three thermal load scenarios for Module 1. Table 8-51 lists results for the first 10,000 years after repository closure under Module 1. The calculated chromium concentrations ranged from about the same to 8 times greater for Module 1 compared to the Proposed Action.

There are two possible comparisons for human health effects for chromium. The Environmental Protection Agency considered safe levels of contaminants in drinking water and the ability to achieve these levels with the best available technology when it established its Maximum Contaminant Level Goals. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (0.0000062 pound per cubic foot) (40 CFR Part 141.51). The other measure for comparison is the reference dose factor for chromium, which is 0.005 milligram per kilogram (0.0004 ounce per pound) of body mass per day (EPA 1998b, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal.

The analysis did not evaluate the groundwater concentrations listed in Table 8-51 for human health effects (for example, latent cancer fatalities) because there is insufficient epidemiological or toxicological data to determine the carcinogenic potency of hexavalent chromium by the oral route of exposure (EPA 1998a, page 48). (Soluble chromium occurs in the hexavalent form; see Appendix I.)

The Alloy-22 that would be used as a corrosion-resistant inner layer of the waste package contains 13.5 percent molybdenum. There is no established toxicity standard for molybdenum (in particular, the Environmental Protection Agency has not established a Maximum Contaminant Level Goal for molybdenum). This does not mean that molybdenum is not toxic, only that there is no standard of toxicity.

During the corrosion of the Alloy-22, molybdenum would behave almost the same as the chromium. Due to the corrosion conditions, molybdenum would dissolve in a highly soluble hexavalent form. Therefore, the source term for molybdenum would be 0.614 times the source term for chromium (the ratio of molybdenum inventory to chromium inventory). All the mechanisms and parameters would be the same

Table 8-51. Peak chromium groundwater concentrations (milligram per liter)[a] for 10,000 years after closure at four locations for high, intermediate, and low thermal load scenarios under the Proposed Action and Inventory Module 1.[b]

Inventory	Thermal load scenario	Maximally exposed individual	Mean	95th-percentile
Proposed Action	High	At 5 kilometers[c]	0.0085	0.037
		At 20 kilometers	0.0028	0.012
		At 30 kilometers	0.0018	0.0063
		At 80 kilometers	0.00022	0.00061
	Intermediate	At 5 kilometers	0.0029	0.0096
		At 20 kilometers	0.0023	0.010
		At 30 kilometers	0.00080	0.0038
		At 80 kilometers	0.000031	0.00015
	Low	At 5 kilometers	0.0046	0.016
		At 20 kilometers	0.0018	0.0083
		At 30 kilometers	0.00067	0.0033
		At 80 kilometers	0.000053	0.00034
Inventory Module 1	High	At 5 kilometers	0.032	0.14
		At 20 kilometers	0.018	0.10
		At 30 kilometers	0.0057	0.027
		At 80 kilometers	0.00029	0.00070
	Intermediate	At 5 kilometers	0.023	0.083
		At 20 kilometers	0.0089	0.042
		At 30 kilometers	0.0032	0.017
		At 80 kilometers	0.00019	0.00057
	Low	At 5 kilometers	0.0093	0.035
		At 20 kilometers	0.0050	0.022
		At 30 kilometers	0.0020	0.0084
		At 80 kilometers	0.000074	0.00026

a. To convert from milligram per liter to pounds per cubic foot, multiply by 0.0000624.
b. Based on 100 simulations of total system performance, using random samples of uncertain parameters.
c. To convert kilometers to miles, multiply by 0.62137.

as those for chromium, so modeling is unnecessary. The analysis assumed that molybdenum would be present in the water at concentrations 0.614 times those reported in Table 8-51 for chromium.

8.3.1.2.3 *Atmospheric Radioactive Material Impacts*

Using the analysis methods described in Section 5.5, DOE estimated the impacts of carbon-14 releases to the atmosphere for Inventory Module 1. Table 8-52 compares these findings to the Proposed Action

Table 8-52. Atmospheric radioactive material impacts for carbon-14.

			For local population within 84 kilometers[a]		
Inventory	Maximum release rate (microcurie per year)	Time of maximum release (years after closure)	Maximum individual dose rate (rem per year)	Maximum population dose (person-rem)	Maximum population LCFs[b]
Proposed Action	0.098	19,000	7.8×10^{-15}	2.2×10^{-10}	1.1×10^{-13}
Inventory Module 1	0.11	27,000	8.8×10^{-15}	2.4×10^{-10}	1.2×10^{-13}

a. 84 kilometers = about 52 miles.
b. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contacting a fatal cancer for individuals and expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (NCRP 1993a, page 31).

carbon-14 impacts. The important difference in the atmospheric carbon-14 impacts for Module 1 and for the Proposed Action is that the number of waste packages containing spent nuclear fuel would increase by approximately 67 percent, providing more carbon-14 for atmospheric release.

The estimated maximum release rate to the air for gaseous-phase carbon-14 would be 0.11 microcurie a year, about 27,000 years after repository closure. This compares to a release rate of 0.098 microcurie per year about 19,000 years after repository closure for the Proposed Action. The 0.11 microcurie-per-year release corresponds to an 8.8×10^{-15} rem-per-year average dose to individuals within 80 kilometers (50 miles). The maximum population dose to the 28,000 people within 80 kilometers would be 2.4×10^{-10} person-rem. This dose rate corresponds to 1.2×10^{-13} latent cancer fatality at the maximum release rate of carbon-14. Over a 70-year period, which corresponds to a lifetime for an individual, this annual dose rate yields a dose of 1.7×10^{-8} rem, corresponding to 8.5×10^{-12} latent cancer fatality during the 70-year period of the maximum release rate. In general, the impacts would be about 13 percent higher for Inventory Module 1 than for the Proposed Action.

8.3.1.3 INCREMENTAL IMPACTS FOR INVENTORY MODULE 2

DOE addressed the long-term consequences from Inventory Module 2 by analyzing the effects of disposing waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in addition to the material in Inventory Module 1. Table 8-35 lists the average inventory of the additional waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The following sections discuss these impacts in terms of waterborne radioactive releases, chemically toxic materials waterborne release, and atmospheric radioactive material releases.

8.3.1.3.1 *Waterborne Radioactive Material Impacts*

The addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes is the only difference between Inventory Modules 1 and 2. Therefore, a complete repetition of the total systems modeling to evaluate the impacts attributable to adding these wastes was unnecessary. Rather, DOE (1998a, Volume 3, pages 2-40 to 2-41) performed a single *expected-value* simulation (using the mean of every probabilistic input parameter) for each thermal load scenario and location, specifying only the Greater-Than-Class-C and Special-Performance-Assessment-Required waste as the radionuclide inventory. The results of these expected-value simulations constitute the additional impacts of Inventory Module 2 over those of Module 1. In addition, they represent the dose attributable solely to the Greater-Than-Class-C and Special-Performance-Assessment-Required waste. By contrasting the expected-value simulation results for Module 2 to the comparable expected-value results for Module 1, the analysis estimated the incremental impact.

Table 8-53 lists the incremental (that is, the increase in) consequences for a maximally exposed individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 during 10,000 years and 1 million years following repository closure. The increases in Table 8-53 are expressed in terms of the percent increase in peak dose to the maximally exposed individual. Peak impacts from waterborne radioactive materials for Module 2 would be less than 2 percent higher for the first 10,000 years after repository closure and less than one-half of one percent higher for the first 1 million years after repository closure compared to Module 1. Therefore, the waterborne radioactive material impacts for Modules 1 and 2 are essentially equivalent in both periods.

8.3.1.3.2 *Waterborne Chemically Toxic Material Impacts*

The Proposed Action impacts described in Section 5.6.3 for uranium would be about 100,000 times smaller than a threshold concentration based on the reference dose for elemental uranium of 0.003

Table 8-53. Percentage increase in peak dose rate under Inventory Module 2 over the peak dose rate under Inventory Module 1 for a maximally exposed individual during 10,000 and 1 million years after repository closure.

Postclosure period	Maximally exposed individual	Thermal load		
		High	Intermediate	Low
10,000 years	At 5 kilometers[a]	1.8	0.70	0
	At 20 kilometers	1.6	0.55	0
	At 30 kilometers	0.99	0.0033	0
	At 80 kilometers	0	0	0
1,000,000 years	At 5 kilometers	0.0015	0.0018	0.0069
	At 20 kilometers	0.0043	0.0025	0.0024
	At 30 kilometers	0.0030	0.0046	0.0044
	At 80 kilometers	0.30	0.34	0.29

a. To convert kilometers to miles, multiply by 0.62137.

milligram per kilogram per day (EPA 1999d, all). The Environmental Protection Agency has not established a Maximum Contaminant Level Goal for elemental uranium. The 70-percent increase in the uranium inventory for Inventory Module 2 (see Table 8-36) would result in impacts that would be much smaller than those for the threshold concentration. Therefore, uranium would not present a substantial impact as a chemically toxic material under Module 2.

Using the same modeling methods as those described in Chapter 5 (and in greater detail in Appendix I), the analysis calculated the impacts of chromium as a chemically toxic material for Inventory Module 2. Just as with the radioactive waterborne impacts, the chromium impacts for Module 2 were modeled as an incremental impact over Module 1 using *expected-value* simulations. Table 8-54 lists the results for the first 10,000 years after repository closure in terms of the percentage increase in chromium concentrations at the various well locations over Module 1 impacts.

Table 8-54. Percentage increase in peak chromium groundwater concentrations (milligrams per liter)[a] under Inventory Module 2 over the peak chromium groundwater concentrations for Inventory Module 1 for 10,000 years after repository closure.

Postclosure period	Maximally exposed individual	Thermal load		
		High	Intermediate	Low
10,000 years	At 5 kilometers[b]	4.5	4.8	15.
	At 20 kilometers	4.5	4.5	4.4
	At 30 kilometers	4.5	4.4	4.3
	At 80 kilometers	4.1	1.5	5.4

a. To convert from milligram per liter to pounds per cubic foot, multiply by 0.0000624.
b. To convert kilometers to miles, multiply by 0.62137.

There are two possible comparisons for human health effects for chromium. The Environmental Protection Agency considered safe levels of contaminants in drinking water and the ability to achieve these levels with the best available technology when it established its Maximum Contaminant Level Goals. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (0.0000062 pound per cubic foot) (40 CFR Part 141.51). The other measure for comparison is the reference dose factor for chromium, which is 0.005 milligram per kilogram (0.0004 ounce per pound) of body mass per day (EPA 1998a, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal.

The analysis made no attempt to express the groundwater concentrations listed in Table 8-54 in terms of human health effects (for example, latent cancer fatalities) because there is a lack of sufficient epidemiological or toxicological data for determining the carcinogenicity of hexavalent chromium by the oral route of exposure (EPA 1998a, page 48) [soluble chromium occurs in the hexavalent form (see Appendix I)].

The Alloy-22 that would be used as a corrosion resistant inner layer of the waste package contains 13.5 percent molybdenum. There is no established toxicity standard for molybdenum (in particular, the Environmental Protection Agency has not established a Maximum Contaminant Level Goal for molybdenum). This does not mean that molybdenum is not toxic, only that there is no standard of toxicity.

During the corrosion of the Alloy-22, molybdenum would behave almost the same as the chromium. Due to the corrosion conditions, molybdenum would dissolve in a highly soluble hexavalent form. Therefore, the source term for molybdenum would be 0.614 times the source term for chromium (the ratio of molybdenum inventory to chromium inventory). All the mechanisms and parameters would be the same as those for chromium, so modeling is unnecessary. The analysis assumed that molybdenum would be present in the water at concentrations 0.614 times those listed in Table 8-54 for chromium.

8.3.1.3.3 *Atmospheric Radioactive Material Impacts*

DOE did not perform detailed analyses of impacts from atmospheric releases of carbon-14 for Inventory Module 2. While the waste packages that would be in addition to those for Module 1 would have an average carbon-14 inventory about triple that of the average waste package of commercial spent nuclear fuel, very little of the additional carbon-14 would be in gaseous form (see Table 8-38). This is because only commercial spent nuclear fuel waste packages contain a relatively large amount of gaseous carbon-14, and Module 2 includes the same number of commercial spent nuclear fuel packages as Module 1. The waste packages containing Greater-Than-Class-C waste and Special-Performance-Assessment-Required wastes that would not contain large quantities of gaseous carbon-14. Therefore, the atmospheric radioactive material impacts for Module 2 would be essentially the same as those for Module 1.

8.3.2 CUMULATIVE IMPACTS FROM INVENTORY MODULE 1 OR 2 AND OTHER FEDERAL, NON-FEDERAL, AND PRIVATE ACTIONS

This section discusses potential cumulative impacts from other Federal, non-Federal, and private actions that could contribute to doses at the locations considered in the performance assessment of the Yucca Mountain Repository. The actions identified with the potential for long-term cumulative impacts are past, present, and reasonably future actions at the Nevada Test Site and past actions at the low-level radioactive waste disposal facility near Beatty, Nevada.

8.3.2.1 Past, Present, and Reasonably Foreseeable Future Actions at the Nevada Test Site

Historically, the primary mission of the Nevada Test Site was to conduct nuclear weapons tests. Nuclear weapons testing and other activities have resulted in radioactive contamination and have the potential for radioactive and nonradioactive contamination of some areas of the Nevada Test Site. These areas and the associated contamination and the potential for contamination were evaluated for potential cumulative impacts with postclosure impacts from the proposed Yucca Mountain Repository. This section discusses these Nevada Test Site activities, the locations where these activities occurred, and the potential for cumulative long-term impacts with the repository.

Unless otherwise identified, DOE derived the information in this section from the Nevada Test Site Final EIS (DOE 1996f, all). The Yucca Mountain Repository site is in the southwestern portion of the Nevada Test Site along its western boundary, as shown in Figure 8-3.

At the Nevada Test Site, seven categories of activities have resulted in radioactive contamination or have the potential to result in radioactive and nonradioactive contamination:

1. *Atmospheric Weapons Testing.* One hundred atmospheric detonations occurred before the signing of the Limited Test Ban Treaty in August 1963. Atmospheric tests included detonations at ground level, from towers or balloons, or from airdrops.

2. *Underground Nuclear Testing.* Approximately 800 underground nuclear tests have occurred at the Nevada Test Site. Figure 8-3 shows the locations of these tests in relation to Yucca Mountain. They included deep underground tests to study weapons effects, designs, safety, and reliability, and shallow underground tests to study the peaceful application of nuclear devices for cratering.

3. *Safety Tests.* Between 1954 and 1963, 16 above-ground tests studied the vulnerability of weapons designs to possible accident scenarios.

4. *Nuclear Rocket Development Station.* Twenty-six experimental tests of reactors, nuclear engines, ramjets, and nuclear furnaces occurred between 1959 and 1973. Figure 8-3 shows the location of the Nuclear Rocket Development Station.

5. *Shallow Land Radioactive Waste Disposal.* DOE disposed of some radioactive waste generated during the testing in shallow cells, pits, and trenches. Because of the site characteristics, notably the absence of a groundwater pathway, shallow burial continues to be an important waste disposal activity at the Nevada Test Site. Section 8.3.2.1.3 discusses present and potential future low-level radioactive waste disposal activities.

6. *Crater Disposal.* DOE disposed of contaminated soils and equipment collected during the decontamination of atmospheric testing areas and the consolidation of radioactively contaminated structures, and other bulk wastes, in subsidence craters at Yucca Flat in Area 3. Figure 8-3 shows the location of the Area 3 Radioactive Waste Management Site.

7. *Greater Confinement Disposal.* In 1981, greater confinement disposal began at Area 5 for low-level radioactive wastes not suitable for shallow land disposal. Figure 8-3 shows the location of the Area 5 Radioactive Waste Management Site.

Table 8-55 lists the approximate inventory for each of these categories. The unimportance of several categories is apparent; atmospheric testing, shallow underground testing, safety testing, and nuclear rocket development all resulted in a less-than-40-curie source term. Additionally, the inventories represented by crater disposal and shallow-land disposal were determined to not be important to cumulative impact considerations. Only the deep underground testing and greater confinement disposal categories represent substantial inventories that could, when combined with the repository inventory, result in increased cumulative impacts.

8.3.2.1.1 *Underground Nuclear Testing*

Declassification of the summed radionuclide source term (total radioactivity of all radionuclides) that remains within 100 meters (330 feet) of the water table has enabled an updated estimate of the total radionuclide source term remaining below the ground surface as a result of underground testing. As of

Table 8-55. Summary of radioactivity on the Nevada Test Site (January 1996).[a]

Source	Area	Environmental media	Major known isotopes or wastes	Depth range	Approximate inventory (curies)
Atmospheric weapons testing	Aboveground nuclear weapon proving area	Surficial soils and test structures	Americium, cesium, cobalt, plutonium, europium, strontium	At land surface	20
Underground testing: shallow underground tests	Underground nuclear testing areas	Soils and alluvium	Americium, cesium, cobalt, europium, plutonium, strontium	Less than 61 meters[b]	1 at land surface; unknown at depth
Underground testing: deep underground tests	Underground nuclear testing areas	Soils, alluvium, and consolidated rock	Tritium, fission, and activation products	Typically less than 640 meters, but might be deeper	More than 300 million, approximately 110 million are below or within 100 meters (330 feet) above the water table and are available for groundwater transport
Safety tests	Aboveground experimental areas	Surficial soils	Americium, cesium, cobalt, plutonium, strontium	Less than 0.9 meter	35
Nuclear rocket development area	Nuclear rocket motor, reactor, and furnace testing area	Surficial soils	Cesium, strontium	Less than 3 meters	1
Shallow land disposal	Waste disposal landfills	Soils and alluvium	Dry-packaged low-level and mixed wastes	Less than 9 meters	500,000[c,d]
Crater disposal	Test-induced subsidence crater with sidewalls, cover, and drainage	Soils and alluvium	Bulk contaminated soils and equipment	Less than 30 meters	1,250[c,e]
Greater confinement disposal	Monitored underground waste disposal	Soils and alluvium	Tritium, americium	37 meters	9.3 million[c,f]

a. Source: DOE (1996f, page 4-6).
b. To convert meters to feet, multiply by 3.2808.
c. Inventory at time of disposal (not corrected for decay).
d. Inventory does not include prospective future low-level radioactive and mixed waste disposal (see Section 8.3.2.1.3).
e. Volume of waste considered for inventory was approximately 205,000 cubic meters (7.25 million cubic feet).
f. Volume of waste considered for inventory was approximately 300 cubic meters (10,000 cubic feet).

January 1, 1994, the estimated total radionuclide source term for all tests was 300 million curies (DOE 1996f, page 4-85). Of that amount, an estimated 110 million curies were below or within about 100 meters (330 feet) above the water table (DOE 1996f, page 4-126). There is some uncertainty related to the Nevada Test Site estimates; the Nevada Test Site EIS contains additional details on the development of the estimated total source term from underground nuclear tests (DOE 1996f, pages 4-126 to 4-130). There is recent evidence of plutonium migration from one underground test. Groundwater monitoring results indicate that plutonium has migrated about 1.3 kilometers (0.8 mile), possibly facilitated by the movement of very small and relatively mobile particles called *colloids* in the groundwater (Kersting et al.

1999, page 59). No radioactive contamination attributable to underground tests has been detected in monitoring wells off the Nevada Test Site. DOE is conducting further monitoring and research to study these and other potential radionuclide migration phenomenon.

The above information indicates that groundwater could transport radionuclides produced during underground nuclear tests at the Nevada Test Site. This transport could ultimately result in releases from underground testing at the same sites analyzed for releases from the repository in this EIS. Long-term performance assessment calculations for the underground testing inventory have not been made with the same rigor as was done for the proposed Yucca Mountain Repository. Nevertheless, DOE calculated a conservative, maximum potential individual dose that would be likely to result from the underground test inventory. The assumptions of this bounding calculation were:

- The total 300-million-curie radionuclide inventory from underground testing, excluding the tritium inventory, would be available for transport. [Tritium's short half-life (about 12.5 years) would mean that the tritium inventory would be depleted through radioactive decay to insignificant levels in about 200 years, long before any Yucca Mountain releases would occur. Tritium constitutes about 90 percent of the total underground testing inventory (DOE 1996f, Table 4-27, pages 4-128 and 4-129)].

- The total underground testing inventory available for transport would migrate through the same locations as those considered in this EIS for dose calculations for releases from the repository. [This is very conservative because much of the water migrating from the underground test locations would discharge to locations other than any releases from the proposed repository, such as Sarcobatus Flats, Oasis Valley, Ash Meadows, or the Amargosa Desert (DOE 1996f, page 4-117)].

- Conservative dilution factors would account for isotopic dilution of carbon-14 by interaction with nonradioactive carbon, removal of technetium through precipitation caused by reducing conditions along the carbonate aquifer flowpaths, dilution in uncontaminated water from the recharge over the Nevada Test Site, and aquifer mixing in transport.

Using the aforementioned conservative assumptions, the maximum potential dose from the underground testing inventory is calculated to be 0.2 millirem per year (based on calculations in the Viability Assessment for radionuclides that would influence dose in 10,000 years). Thus, the maximum cumulative impact of the Proposed Action in 10,000 years, for example [using the mean impact at 20 kilometers (12 miles); see Table 8-39], would be 0.22 millirem per year (the Yucca Mountain Repository impact) plus 0.2 millirem per year (the conservative maximum dose estimate resulting from underground testing), or 0.42 millirem per year. No estimate was made for 1 million years, but the cumulative impact contribution from underground testing is likely to be similar.

There is a high degree of uncertainty associated with this estimate, but the use of bounding assumptions ensures that any reduction in uncertainty would only lower the already low estimated impact. The uncertainty in the estimates is related to several factors. There is a relatively limited amount of information on the groundwater system between the area where underground testing occurred and the Yucca Mountain site. Therefore, the speed of groundwater travel, the relationship between aquifers (mixing), dilution rates, and other factors can only be generally approximated. In addition, the estimates of contaminant travel time from the underground tests are based on one data set from one well over a very short time (fewer than 50 years) and then extrapolated to 10,000 years. As mentioned above, these impact estimates were not performed with the same rigor as those for the long-term performance assessment for the repository.

8.3.2.1.2 *Greater Confinement Disposal*

The waste disposed of under Greater Confinement Disposal constitutes a radiological source term that is less than 10 percent of the repository radionuclide source term immediately available for groundwater transport when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, Greater Confinement Disposal wastes could result in an increase of no more than approximately 10 percent to the impacts associated with the repository.

8.3.2.1.3 *Future Nevada Test Site Low-Level Waste Disposal*

The Nevada Test Site is a disposal site for low-level radioactive waste generated by DOE-approved generators. Managed radioactive waste disposal operations began in the early 1960s, and DOE has disposed of low-level, transuranic, mixed, and classified low-level wastes in selected pits, trenches, landfills, and boreholes on the Nevada Test Site. Environmental impacts from the disposal of low-level waste at the Nevada Test Site are discussed in the Nevada Test Site Final EIS (DOE 1996f, pages 2-15 to 2-17). The current source term of low-level and mixed wastes in shallow land disposal on the Nevada Test Site does not constitute a substantial inventory in relation to the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). However, shallow burial continues to be an important waste disposal activity at the Nevada Test Site. Therefore, this section evaluates reasonably foreseeable future activities in this category as a potential cumulative impact.

Waste disposal activities on the Nevada Test Site occur at two specific locations. They are the Area 3 and Area 5 Radioactive Waste Management Sites. The Area 3 Radioactive Waste Management Site is on Yucca Flat and covers an area of approximately 0.2 square kilometer (50 acres). DOE uses conventional landfill techniques to dispose of contaminated debris from the Nevada Test Site Atmospheric Testing Debris Disposal Program and packaged bulk low-level waste from other DOE sites in subsidence craters from underground nuclear tests. The estimated total remaining capacity for low-level waste in the Area 3 site is 1.8 million cubic meters (64 million cubic feet) (DOE 1998l, Section A.5.2).

DOE has used the Area 5 Radioactive Waste Management Site since 1961 to dispose of low-level waste and classified low-level waste from Nevada Test Site operations. In 1978, the Nevada Test Site began accepting low-level waste generated by other DOE sites. The total area of the Area 5 site is 3 square kilometers (740 acres). The developed portion occupies 0.37 square kilometer (92 acres) in the southeast corner and contains 17 landfill cells (pits and trenches), 13 Greater Confinement Disposal boreholes, and a transuranic waste storage pad. DOE proposes to locate the Mixed Waste Disposal Unit, which will be a landfill, on about 0.18 square kilometers (45 acres) of the Area 5 site, immediately north of the developed Radioactive Waste Management Site landfill area. The design has been completed, the unit has been included in the Resource Conservation and Recovery Act permit application, and the environmental assessment is being updated. The estimated total remaining capacity for low-level waste in the Area 5 Radioactive Waste Management Site is 1.2 million cubic meters (42 million cubic feet) (DOE 1998l, Section A.5.3).

DOE projects the total life cycle of low-level waste disposal at the Nevada Test Site to be 217,000 cubic meters (7,700,000 cubic feet) of low-level waste by volume (DOE 1998l, Table 2.9):

- 22,000 cubic meters (78,000 cubic feet) during the period from 1996 through 2000
- 85,000 cubic meters (3,000,000 cubic feet) during the period from 2001 through 2030
- 110,000 cubic meters (3,900,000 cubic feet) during the period from 2031 through 2070

To date, DOE has projected only the volumetric waste disposal, not the total radioactivity associated with future low-level waste that it would dispose of. Radiological performance assessment information is required to provide a more accurate evaluation of disposal criteria (DOE 1998i, Executive Summary).

The Final Waste Management Programmatic EIS (DOE 1997b, Summary) reported volumes of radioactive waste DOE may dispose of at the Nevada Test Site for "current plus 20 years" of waste disposal. The current inventory plus 20 years of additional disposal inventory would total 3,000 cubic meters (106,000 cubic feet) of low-level mixed waste, 1,700 cubic meters (60,000 cubic feet) of low-level waste, and 610 cubic meters (21,500 cubic feet) of transuranic waste (DOE 1997b, Summary, Page 102). The Nevada Test Site Final EIS (DOE 1996f, Table 4-1, page 4-6) estimates the total current inventory already in shallow disposal at the Nevada Test Site to be 500,000 curies at the time of disposal (uncorrected for decay to the present time).

According to the Final Waste Management Programmatic EIS, the only expected groundwater impacts from low-level mixed, low-level radioactive, and transuranic waste disposal at the Nevada Test Site in excess of regulatory limits are for the hazardous chemicals 1,2-dichloroethane, methylene chloride, and benzene, and those only under Regionalized Alternative 3 and the Preferred Alternative in that EIS (DOE 1997b, page 11-61). None of these hazardous chemicals would be in the Yucca Mountain Repository inventory, so there would be no potential cumulative impacts from those chemicals from the Proposed Action or Inventory Module 1 or 2.

In summary, the source term of shallow-land disposal sites for past and reasonably foreseeable future disposal at the Nevada Test Site would be small in comparison to the radionuclide source term available for groundwater transport from the repository. Therefore, cumulative long-term impacts from shallow-land disposal at the Nevada Test Site with the repository, if any, would be very small.

8.3.2.2 Past Actions at Beatty Low-Level Radioactive Waste Disposal Facility

A low-level radioactive waste disposal facility, formerly operated by U.S. Ecology, a subsidiary of American Ecology, is 16 kilometers (10 miles) southeast of Beatty, Nevada, and 180 kilometers (110 miles) northwest of Las Vegas. This site is about 15 kilometers (9.3 miles) west of the proposed Yucca Mountain Repository (see Figure 8-2). The disposal facility, which opened in 1962, covers roughly 0.14 square kilometer (35 acres) of unlined trenches. It remains open for hazardous waste disposal, but acceptance of low-level radioactive waste ended December 31, 1992 (DOE 1997p, Chapter 4, Table 4-17). The Nevada State Health Division formally accepted permanent custody of the low-level radioactive commercial waste disposal in a letter to American Ecology dated December 30, 1997 (AEC 1998, all).

From 1962 through 1992, the inventory shipped to the Beatty low-level radioactive waste facility totaled 137,000 cubic meters (4.8 million cubic feet) in volume (DOE 1997p, Chapter 4, Table 4-17) with radioactivity of about 640,000 curies (DOE 1997p, Chapter 4, Table 4-18). The radioactivity in this sum was measured by year of shipment (that is, it is not corrected for decay since that time).

The Manifest Information Management System (MIMS 1999, all) calculated the total radionuclide inventory the Beatty facility received from 1986 through 1992, which represents 29 percent of the total undecayed inventory at that facility. Even if multiplied by a factor of 3 to 4 to compensate for the period (1962 to 1985) for which the Manifest Information Management System did not provide information, the source term represents a small percentage of the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, cumulative long-term impacts from the Beatty Low-Level Radioactive Waste Disposal Facility with the repository would be very small.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. Paralleling the transportation analyses of the Proposed Action in Chapter 6, potential national transportation cumulative impacts from Inventory Module 1 or 2, and past, present, and reasonably foreseeable future actions, are presented in Section 8.4.1. Potential cumulative impacts with construction and operation of the Nevada transportation implementing rail and heavy-haul truck alternatives are included in Section 8.4.2.

The shipment of Inventory Module 1 or 2 to the repository would use the same transportation routes, but would take more shipments and an additional 14 years compared to the Proposed Action. Table 8-2 lists the estimated number of shipments for Modules 1 and 2. Impacts from Module 1 or 2 would be similar because the shipping rate would be the same for spent nuclear fuel and high-level radioactive waste and only about 3 percent more shipments would be made over the 38-year period under Module 2 to transport Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. Because the difference in impacts between Inventory Modules 1 and 2 would be small, the following discussions present the impacts from both modules as being the same.

8.4.1 NATIONAL TRANSPORTATION

This section describes potential cumulative impacts from shipping Inventory Module 1 or 2 from commercial nuclear generating sites and DOE facilities to the proposed Yucca Mountain Repository (Section 8.4.1.1). Section 8.4.1.2 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Inventory Module 1 or 2 Impacts

This section describes the potential cumulative impacts of loading operations at generating sites and incident-free radiological impacts, vehicle emission impacts, and accident impacts associated with transportation activities for Inventory Module 1 or 2. Cumulative impact results are provided for the mostly legal-weight truck and mostly rail scenarios which are described in Chapter 6. The section also describes potential cumulative impacts from transportation of other materials, personnel, and repository-generated waste for Modules 1 or 2. Appendix J contains additional detailed analysis results.

Loading operations would be extended for an additional 14 years to load the greater quantities of spent nuclear fuel and high-level radioactive waste under Inventory Module 1 or 2. The impacts of routine loading operations described for the Proposed Action in Chapter 6, Section 6.2.2, would increase for Module 1 or 2 due to the additional inventory. DOE would not expect any releases of radioactive material from loading operations that would cause public impacts from either the Proposed Action or Module 1 or 2. Table 8-56 lists estimated radiological and industrial hazard impacts to involved workers for the routine loading operations under Module 1 or 2. The Proposed Action impacts are listed for comparison.

Because noninvolved workers would not have tasks that involved radioactive exposure, there would be no or very small radiological impacts to noninvolved workers. For the reasons identified in Chapter 6, Section 6.1.2.2, industrial hazard impacts to noninvolved workers would be about 25 percent of the impacts to the individual worker shown in Table 8-56.

The impacts of loading accident scenarios under Inventory Module 1 or 2 would be the same as those described for the Proposed Action in Chapter 6, Section 6.2.4.1. The same type of single accident event and its impacts are applicable to shipments under the Proposed Action or Module 1 or 2. As summarized

Table 8-56. Radiological and industrial hazard impacts to involved workers from loading operations.[a,b]

Impact	Proposed Action[b]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological				
Maximally exposed individual				
Dose (rem)[c]	12	12	12	12
Probability of latent cancer fatalities	0.005	0.005	0.005	0.005
Involved worker population				
Dose (person-rem)	14,000	5,000	28,000	9,000
Number of latent cancer fatalities	6	2	11	4
Industrial hazards				
Total recordable cases[d]	150	65	280	110
Lost workday cases[e]	66	29	140	50
Fatalities[f]	0.14	0.06	0.3	0.1

a. Includes all involved workers at all facilities.
b. Source: Chapter 6, Section 6.2.
c. Assumes 500 millirem per year to radiation workers. The average individual exposure was assumed to be 24 years for both the Proposed Action and Inventory Module 1 or 2 since 24 years is a conservatively long time to assume an individual would be involved in loading operations.
d. Total recordable cases (of injury and illness) based on a 1992-1997 DOE complex loss incidence rate of 0.03 (DOE 1999c, all).
e. Lost workday cases based on a 1992-1997 DOE complex loss incidence rate of 0.31.
f. Fatalities based on a 1988-1997 DOE complex loss incidence rate of 0.000029.

in Chapter 6, Section 6.2.4.1, the analysis results indicate that there would be no or very small potential radiological consequences from loading accident scenarios involving spent nuclear fuel or high-level radioactive waste. These consequences would bound the consequences from similar accidents involving Greater-Than-Class-C or Special-Performance-Assessment-Required waste because of the lower available radionuclide inventory (see Appendix A).

Table 8-57 lists radiological impacts to involved workers and the public and vehicle emission impacts from incident-free transportation for the mostly legal-weight truck and mostly rail scenarios. The analysis

Table 8-57. Radiological and vehicle emission impacts from incident-free national transportation.

Category	Proposed Action[a,b]		Inventory Module 1 or 2[c]	
	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]
Involved worker				
Collective dose (person-rem)	11,000	1,900 - 2,300	20,000	3,000 - 3,800
Estimated number of latent cancer fatalities	4.5	0.77 - 0.93	8.0	1.2 - 1.5
Public				
Collective dose (person-rem)	35,000	3,300 - 5,000	62,000	5,000 - 8,100
Estimated number of latent cancer fatalities	18	1.6 - 2.5	31	2.5 - 4.0
Estimated vehicle emission-related fatalities	0.6	0.3	1.1	0.46 - 0.52

a. Source: Chapter 6, Section 6.2.3.
b. Impacts are totals for shipments over 24 years.
c. Impacts are totals for shipments over 38 years.
d. Includes rail shipments of naval spent nuclear fuel to Nevada, and intermodal transfer station and heavy-haul truck operations for this fuel in Nevada.
e. Includes legal-weight truck shipments from commercial nuclear generator sites that do not have the capacity to handle or load rail casks, and the rail and heavy-haul truck implementing alternatives for Nevada described in Chapter 6.

of impacts for the mostly legal-weight truck scenario assumed that shipments would use commercial motor carriers for highway transportation and general freight commercial services for rail transportation for the naval spent fuel shipments that cannot be transported by legal-weight trucks. The mostly rail analysis accounts for legal-weight truck shipments that would occur for the commercial nuclear generator sites that do not have the capacity to handle or load rail casks. In addition, for the mostly rail analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in conjunction with an intermodal transfer station in Nevada to transport the large rail casks to and from the repository. The range provided in the table for the mostly rail scenario addresses the different possible rail and heavy-haul truck implementing alternatives described in Chapter 6. The lower end of the range reflects use of a branch rail line in Nevada and the upper end of the range reflects use of heavy-haul trucks in Nevada. The involved worker impacts in Table 8-57 include estimated radiological exposures of truck and rail transportation crews and security escorts for legal-weight truck and rail shipments; the public doses account for the public along the route, the public sharing the route, and the public during stops. The Inventory Module 1 or 2 impacts would exceed those of the Proposed Action due to the additional number of shipments.

DOE does not expect radiological impacts for maximally exposed individuals to change from the Proposed Action due to the conservative assumptions used in the analysis of the Proposed Action (see Chapter 6, Section 6.2.3). The assumptions for estimating radiological dose include the use of the maximum allowed dose rate and conservative estimates of exposure distance and time. For example, the U.S. Department of Transportation maximum allowable dose rate of 10 millirem per hour at a distance of 2 meters (6.6 feet) [40 CFR 173.44(b)]was used for estimating exposure to individuals. In addition, the conservative assumptions for exposure distance and time for workers (that is, crew members, inspectors, railyard crew member) and the public (that is, resident along route, person in a traffic jam, person at a service station, resident near a rail stop) for the Proposed Action are unlikely to be exceeded for Inventory Module 1 or 2 (see Chapter 6, Section 6.2.3).

Table 8-58 lists the radiological accident risk and traffic fatalities for transportation by mostly legal-weight truck and mostly rail for Inventory Module 1 or 2. The radiological accident risk measures the total impact of transportation accidents over the entire shipping campaign (24 years for the Proposed Action and 38 years for Module 1 or 2). The consequences from a maximum reasonably foreseeable accident scenario would be identical to those discussed for the Proposed Action (see Chapter 6, Sections 6.2.4.2.1 and 6.2.4.2.2) because the parameters and conditions for the hypothetical accident event involving spent nuclear fuel or high-level radioactive waste would be the same for a shipment under the Proposed Action or Module 1 or 2. In addition, the hypothetical accident would be bounding for accident scenarios involving Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

Table 8-58. Accident risk for mostly legal-weight truck and mostly rail scenarios.

Category	Proposed Action[a]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological accident risk				
Collective dose risk (person-rem)	130	42 – 47	210	64 – 72
Estimated number of latent cancer fatalities	0.07	0.021 - 0.024	0.10	0.032 – 0.036
Traffic accident fatalities	3.9	2.7 – 3.6	7.0	4.6 – 6.2

a. Source: Chapter 6, Section 6.2.4.2.

As summarized in Chapter 6, Section 6.1.3, and further described in Appendix J, in addition to the transportation of spent nuclear fuel and high-level radioactive waste to the repository, other material would require transportation to and from the proposed repository. These materials would include

construction materials, consumables, disposal containers, office and laboratory supplies, mail, and laboratory samples. Required transportation would also include personnel commuting to the Yucca Mountain site and the shipment of repository-generated wastes offsite for treatment, storage, or disposal. The implementation of Inventory Module 1 or 2 would increase this transportation as a result of the additional required subsurface development and the longer time required for repository development, emplacement, and closure. However, even with the increased transportation of other material, personnel, and repository-generated wastes for Module 1 or 2, DOE would expect these transportation impacts to be small contributors to the total transportation impacts on a local, state, and national level with no large cumulative impacts based on the analysis of the Proposed Action in Section 6.1.3. The annual air quality impacts for Inventory Module 1 or 2 would be the same as those conservatively estimated in Section 6.1.3 and, therefore, no cumulative air quality impacts would be expected in the Las Vegas airshed, which is in nonattainment for carbon monoxide. Table 8-59 summarizes fatalities from transporting other materials, personnel, and repository-generated waste. The estimated fatalities assume truck shipments which would have higher potential impacts than shipments by rail. The Proposed Action impacts are listed in the table for comparison.

Table 8-59. Impacts from transportation of materials, consumables, personnel, and waste.[a,b]

	Proposed Action		Inventory Module 1 or 2	
Category	Kilometers[c] traveled	Fatalities	Kilometers traveled (Module 1/Module 2)	Fatalities (Module l/Module 2)
Materials (including disposal containers)	130,000,000	2.5	225,000,000	4.2
Personnel	450,000,000	6.0	650,000,000	8.6
Repository-generated waste				
Hazardous	110,000	0.002	170,000/200,000	0.03/0.04
Low-level radioactive	460,000	0.008	750,000/860,000	0.01/0.02
Nonhazardous solid	560,000	0.01	660,000	0.01
Dual-purpose canisters	1,600,000	0.03	2,700,000	0.05
Totals	**580,000,000**	**8.6**	**1,100,000,000**	**12.9**

a. Totals might differ from sums due to rounding.
b. Source: Appendix J.
c. To convert kilometers to miles, multiply by 0.62137.

8.4.1.2 Cumulative Impacts from the Proposed Action, Inventory Module 1 or 2, and Other Federal, Non-Federal, and Private Actions

The overall assessment of cumulative national transportation impacts for past, present, and reasonably foreseeable future actions concentrated on the cumulative impacts of offsite transportation, which would yield potential radiation doses to a greater portion of the general population than onsite transportation and would result in fatalities from traffic accidents. The collective dose to workers and to the general population was used to quantify overall cumulative radiological transportation impacts. This measure was chosen because it could be related directly to latent cancer fatalities using a cancer risk coefficient and because of the difficulty in identifying a maximally exposed individual for shipments throughout the United States from 1943 through 2047. Operations at the Hanford Site and the Oak Ridge Reservation began in 1943, and 2047 is when the EIS analysis assumed that radioactive material shipments to the repository for Inventory Module 1 or 2 would end. The source of this cumulative transportation impacts analysis is the Yucca Mountain EIS Environmental Baseline File on transportation (TRW 1999u, Section 7.0), with the exception of impacts from the Proposed Action and Module 1 or 2, which are from Table 8-57.

The cumulative impacts of the transportation of radioactive material would consist of impacts from:

- Historic DOE shipments of radioactive material associated with the Nevada Test Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, the Hanford Site, the Oak Ridge Reservation, and naval spent nuclear fuel and test specimens

- Reasonably foreseeable actions that include the transportation of radioactive material identified in DOE Environmental Policy Act analyses; for example, the Nevada Test Site Environmental Impact Statement (DOE 1996f, all), the Department of Energy Spent Nuclear Fuel Management Environmental Impact Statement (DOE 1995a, all; DOE 1996c, all), and the Final Department of Energy Waste Management Environmental Impact Statement (DOE 1997b, all) (see Table 8-60). [Note: Table 8-60 includes reasonably foreseeable projects that include limited transportation of radioactive material (for example, shipment of submarine reactor components from the Puget Sound Naval Shipyard to the Hanford Site for burial, and shipments of uranium billets and low-specific-activity nitric acid from the Hanford Site to the United Kingdom). In addition, for reasonably foreseeable future actions where a preferred alternative was not identified or a Record of Decision has not been issued, the analysis used the alternative estimated to result in the largest transportation impacts. While this is not an exhaustive list of the projects that could include limited transportation of radioactive material, it indicates that the transportation impacts associated with such projects are low in comparison to major projects or general transportation.]

- General radioactive materials transportation that is not related to a particular action; for example, shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities

- Shipments of spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste under the Proposed Action or Inventory Module 1 or 2

Table 8-60 summarizes the worker and general population collective doses from the transport of radioactive material. The estimated total cumulative transportation-related collective worker doses from the mostly legal-weight truck shipments (past, present, and reasonably foreseeable actions) with the Proposed Action would be about 340,000 person-rem (140 latent cancer fatalities), and with Inventory Module 1 or 2 about 370,000 person-rem (150 latent cancer fatalities). The estimated total general population collective doses for the mostly legal-weight truck shipments would be about 340,000 person-rem (170 latent cancer fatalities) with the Proposed Action, and about 390,000 person-rem (200 latent cancer fatalities) with Module 1 or 2. Most of the collective dose for workers and the general population would be due to general transportation of radioactive material. The estimated total number (workers plus population) of latent cancer fatalities with the Proposed Action would be about 310, and about 350 with Module 1 or 2. Over a corresponding period from 1943 to 2033 for the Proposed Action and from 1943 to 2047 for Module 1 or 2, approximately 46 million and 54 million people, respectively, would die from cancer in the United States based on 510,000 annual cancer fatalities (Bureau of the Census 1993, all). The estimated number of transportation-related latent cancer fatalities would be indistinguishable from other cancer fatalities, and the transportation-related latent cancer fatalities would be less than 0.0007 percent of the total number of cancer fatalities.

For transportation accidents involving radioactive material, the dominant risk is due to accidents that are not related to the cargo (traffic or vehicular accidents). Typically, the radiological accident risk (latent cancer fatalities) from transportation accidents is less than 1 percent of the vehicular accident risk (see Table 8-58). In addition, no acute radiological fatalities due to transportation accidents have ever

Table 8-60. Cumulative transportation-related radiological collective doses, latent cancer fatalities, and traffic fatalities.[a]

Category	Collective worker dose (person-rem)	Collective general population dose (person-rem)	Traffic fatalities
Historical DOE shipments (DOE 1996f, all)	330	230	NL[b]
Reasonably foreseeable actions			
Nevada Test Site expanded use (DOE 1996f, all)	--[c]	150[d]	8
Spent nuclear fuel management (DOE 1995a, all; DOE 1996c, all)	360	810	0.77
Waste Management PEIS (DOE 1997b, all)[e]	16,000	20,000	36
Waste Isolation Pilot Plant (DOE 1997o, all)	790	5,900	5
Molybdenum-99 production (DOE 1996j, all)	240	520	0.1
Tritium supply and recycling (DOE 1995e, all)	--	--	0.029
Surplus HEU disposition (DOE 1996k, all)	400	520	1.1
Storage and Disposition of Fissile Materials (DOE 1996e, all)	--	2,400[d]	5.5
Stockpile Stewardship (DOE 1996l, all)	--	38[d]	0.064
Pantex (DOE 1996m, all)	250[f]	490[d]	0.006
West Valley (DOE 1996b, all)	1,400	12,000	3.6
S3G and D1G prototype reactor plant disposal (DOE 1997q, all)	2.9	2.2	0.010
S1C prototype reactor plant disposal (DOE 1996n, all)	6.7	1.9	0.0037
Container system for Naval spent nuclear fuel (USN 1996a, all)	11	15	0.045
Cruiser and submarine reactor plant disposal (USN 1996b, all)	5.8	5.8	0.00095
Submarine reactor compartment disposal (USN 1984, all)	--	0.053	NL
Uranium billets (DOE 1992b, all)	0.50	0.014	0.00056
Nitric acid (DOE 1995h, all)	0.43	3.1	NL
General radioactive material transportation			
1943 to 2033	310,000	260,000	19
1943 to 2047	330,000	290,000	22
Proposed Action			
Mostly legal-weight truck	11,000	35,000	3.9
Mostly rail	1,900 - 2,300	3,300 - 5,000	3.6
Module 1 or 2[g]			
Mostly legal-weight truck	20,000	62,000	7.0
Mostly rail	3,100 - 3,800	5,000 - 8,100	6.2
Total collective dose (total latent cancer fatalities)[h] *and total traffic fatalities*			
Proposed Action			
Mostly legal-weight truck	340,000 (140)	340,000 (170)	83
Mostly rail	330,000 (130)	310,000 (160)	83
Module 1 or 2[g]			
Mostly legal-weight truck	370,000 (150)	390,000 (200)	86
Mostly rail	350,000 (140)	340,000 (170)	85

a. Sources: TRW (1999u, Section 7) except for the Proposed Action and Inventory Module 1 or 2, which are from Table 8-56. All references in this table refer to the original source of information cited in TRW (1999u, Section 7).
b. NL = not listed.
c. -- = reported or included with the general population collective dose.
d. Includes worker and general population collective doses.
e. Includes mixed low-level waste and low-level waste; transuranic waste included in DOE (1997o, Volume 1).
f. Includes all highly enriched uranium shipped to Y-12.
g. The transportation-related radiological collective doses for Inventory Module 1 or 2 include the doses from the Proposed Action (see the definition of Modules 1 and 2 in Section 8.1.2.1).
h. The conversion factors for worker and general population collective dose to latent cancer fatalities are 0.0004 and 0.0005 latent cancer fatality per person-rem, respectively (NCRP 1993a, page 31).

occurred in the United States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

From 1943 through 2033 an estimated 4 million people would be killed in motor vehicle accidents and 180,000 people would be killed by railroad accidents. From 1943 through 2047, an estimated 4.4 million people would be killed in motor vehicle accidents and 200,000 people would be killed in railroad accidents. Based on the estimated number of traffic fatalities for the reasonably foreseeable actions and for the Proposed Action and Inventory Module 1 or 2 listed in Table 8-60, the transport of radioactive material would contribute about 100 fatalities to these totals.

8.4.2 NEVADA TRANSPORTATION

This section analyzes potential cumulative impacts that Inventory Module 1 or 2 and past, present, and other reasonably foreseeable future Federal, non-Federal, and private actions could have on the construction and operation of a branch rail line or the construction and operation of an intermodal transfer station and associated highway upgrades for heavy-haul trucks in the State of Nevada. The analysis included potential cumulative impacts in the vicinity of the five potential branch rail line corridors, the three potential intermodal transfer station locations, and the five associated potential highway routes for heavy-haul trucks.

With respect to potential cumulative impacts from Inventory Module 1 or 2, there would be no cumulative construction impacts because the need for a new branch rail line or new intermodal transfer station and associated highway upgrades for heavy-haul trucks would not change; that is, whatever DOE would build for the Proposed Action would also serve Module 1 or 2. In addition, because the planned annual shipment rate of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository would be about the same for Module 1 or 2 and the Proposed Action, the only cumulative operations impacts would result because of the extra 14 years of shipping time required for Module 1 or 2. With this basis, the operation and maintenance of a branch rail line or an intermodal transfer station and associated highway route for heavy-haul trucks were analyzed for potential cumulative impacts from Module 1 or 2.

Land-use and ownership impacts would be unlikely for the Proposed Action (see Chapter 6, Section 6.3), and DOE expects no cumulative impacts from extending shipping operations from approximately 24 to 38 years. Similarly, DOE expects no cumulative impacts from the extended 14 years of operation for Inventory Module 1 or 2 to air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; and utilities, energy, and materials, the impacts of which were assessed on a per shipment, weekly, or annual basis (see Chapter 6, Section 6.3).

Cumulative impacts from Inventory Module 1 or 2 to occupational and public health and safety are included in the occupational and public health and safety impacts of national transportation in Section 8.4.1. The operation of an intermodal transfer station for more years under Module 1 or 2 would affect waste management impacts. The same waste types and annual quantities would be generated as for the Proposed Action, but the total waste quantities would be about 60 percent more than those for the Proposed Action due to the additional years of operation. However, the small waste quantities generated for Module 1 or 2 would have a minimal impact to the receiving treatment and disposal facilities. Because there would be no large cumulative impacts for any of the resource areas from Module 1 or 2, disproportionately high and adverse cumulative impacts to minority or low-income populations or to Native Americans would be unlikely.

Other than Inventory Module 1 or 2, one other Federal action and several private actions could have the potential for cumulative impacts with the construction and operation of a new branch rail line or intermodal transfer station and associated highway route for heavy-haul trucks.

One private action that could lead to cumulative impacts with the Carlin rail corridor implementing alternative is by Cortez Gold Mine, Inc., which has an existing Pipeline Project mining operation and processing facility (BLM 1996, all), a proposed Pipeline Infiltration Project (BLM 1999b, all), and a possible Pipeline Southeast Expansion Project (BLM 1996, page 5-7) in the Crescent Valley area of Nevada through which the Carlin branch rail line would pass (see Section 8.1.2.3 and Figure 8-4). Because the Carlin corridor would pass through the general area of these projects, there could be cumulative land-use and ownership impacts that would require mitigation. Because the Pipeline Southeast Expansion Project is currently under study, the Final EIS will review new information that

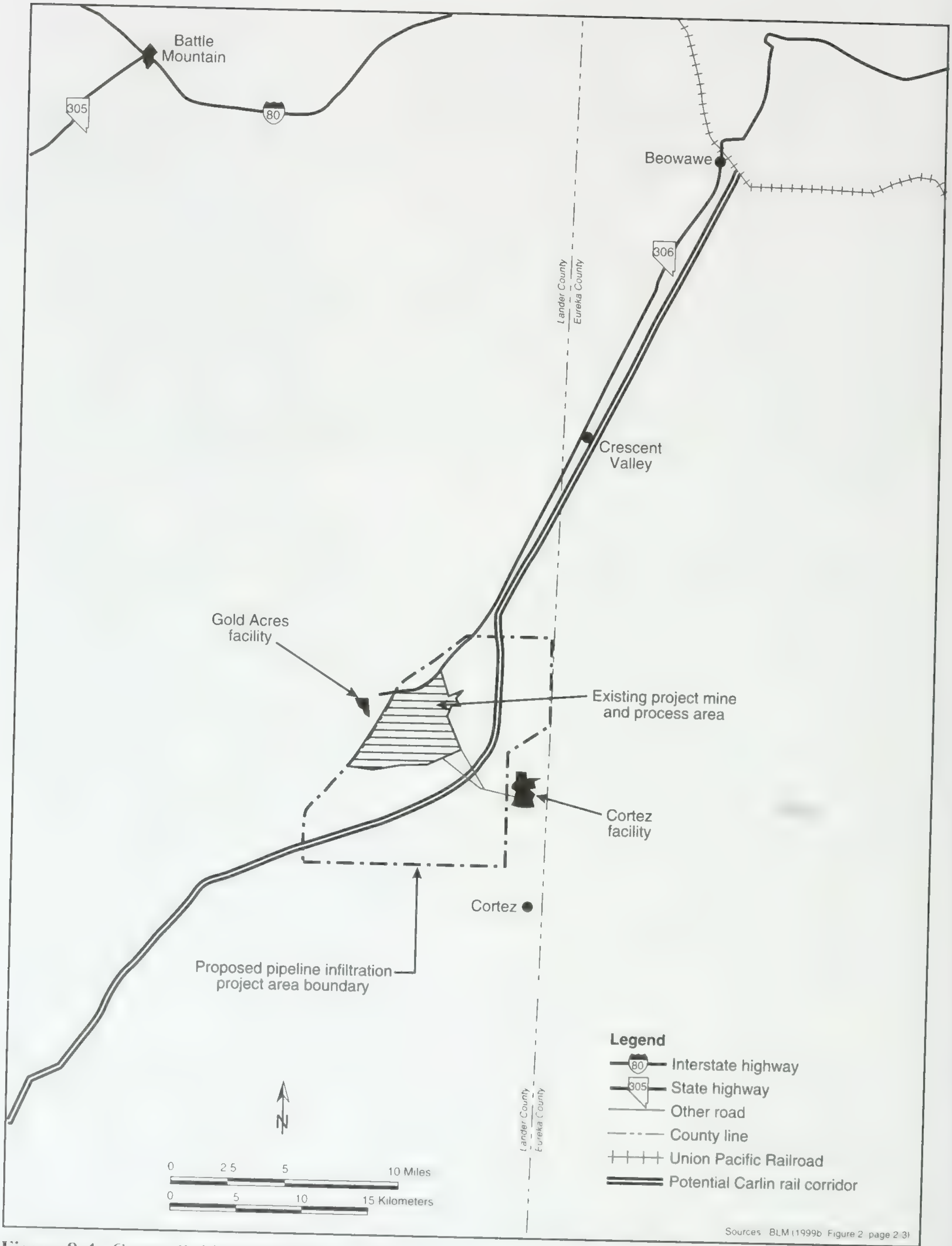


Figure 8-4. Cortez Gold Mine existing pipeline project and proposed pipeline infiltration project.

becomes available on this project for additional cumulative impacts. The analysis for the Carlin rail corridor represents the maximum impact other rail corridor implementing alternatives would have smaller impacts. Cumulative impacts for the mostly legal-weight truck scenario would also have smaller impacts.

Another private action that could result in cumulative impacts would be shared use of a branch rail line that DOE constructed and operated to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository by others (for example, mine operators, private freight shippers) because of the increased rail traffic. Because predicting the increase in rail traffic would be difficult, this analysis cannot estimate the cumulative impacts. There could be some added impacts to all the resource areas beyond those evaluated for the Proposed Action in Chapter 6, but there would also be benefits from the improved economic potential for resource development in interior areas of Nevada as well as greater economic development potential for nearby communities. DOE would have to consider these impacts in any decision it made to allow shared use of the branch rail line.

A Federal action and a private action could lead to cumulative impacts with the construction and operation of the Caliente intermodal transfer station. DOE has specified the Caliente site as one of four possible locations for the construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site (DOE 1998m, pages 2-4 to 2-12). In addition, a commercial venture planned by Apex Bulk Commodities for the Caliente site would construct an intermodal transfer station for the transport of copper concentrate. Figure 8-5 shows a possible layout plan for these intermodal transfer stations at Caliente. Section 8.1 provides more information on the potential DOE and Apex intermodal transfer stations. The following sections describe the potential cumulative impact analysis at the Caliente site from the construction and operation of an intermodal transfer station to support the proposed Yucca Mountain Repository, coupled with an intermodal transfer station for shipment of low-level radioactive waste to the Nevada Test Site and an intermodal transfer station proposed by Apex Bulk Commodities.

8.4.2.1 Land Use and Ownership

The land required for the DOE low-level radioactive waste and Apex intermodal transfer stations would add to the approximately 0.21 square kilometer (50 acres) of property that would be required for the intermodal transfer station that would support the proposed Yucca Mountain Repository. The rail spur and facility for the low-level radioactive waste intermodal transfer station would disturb approximately 0.02 square kilometer (5 acres) of land. The Apex transfer facility would be in a building about 90 by 30 meters (300 by 100 feet). In addition, Apex would have a truck maintenance facility in a building about 30 by 18 meters (100 by 60 feet) that it could share with the low-level radioactive waste intermodal facility. The incremental impacts resulting from the changes in land use associated with the three intermodal transfer stations would not result in a substantial cumulative impact.

8.4.2.2 Air Quality

Air quality cumulative impacts during construction of the three intermodal transfer stations would not be expected to occur since construction activities would likely occur at different times. Even if construction for all three intermodal transfer stations occurred concurrently, administrative controls would be implemented to prevent an adverse impact from collective emissions and dust-generating activities.

During operations, there would be approximately one or two repository rail shipments and three or four associated heavy-haul trucks a day, an average of about three trains and seven trucks a day for DOE low level radioactive waste shipments, and one truck an hour for the Apex copper concentrate transport. At present, an average of one train an hour and light highway traffic travels through Caliente. The incremental increase in air pollutants from rail and highway traffic resulting from the three actions would

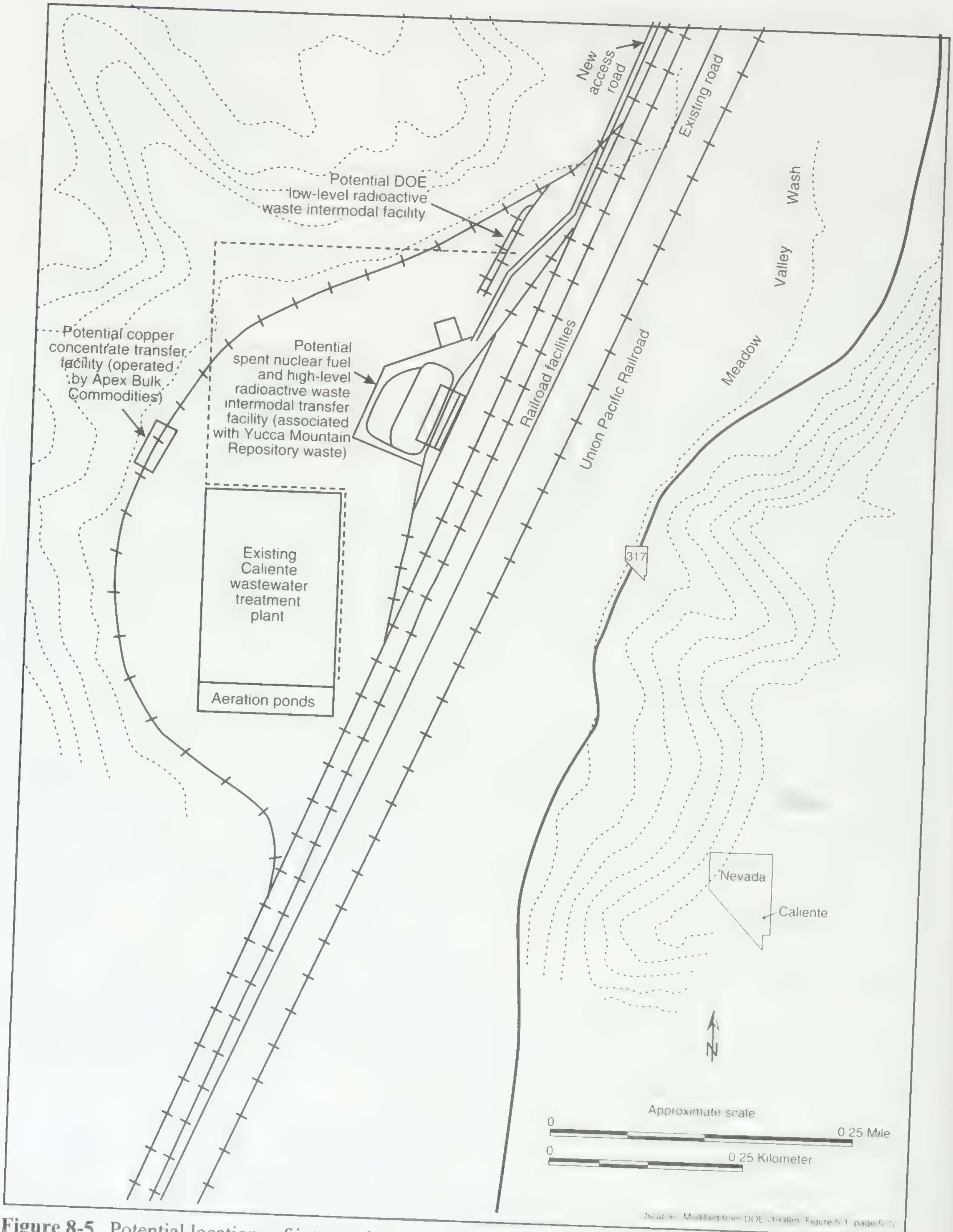


Figure 8-5. Potential locations of intermodal transfer stations at Caliente.

cause slight, temporary increases in pollutants, but would not exceed Federal standards (Chapter 6, Section 6.3.2; DOE 1998m, pages 4-13, 5-5, and 5-8). Criteria pollutants released during routine operations of the intermodal transfer stations would include nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter. DOE expects these emissions would also be well within Federal standards.

8.4.2.3 Hydrology

Surface Water

Mitigation measures used during the construction of the intermodal transfer stations would minimize surface-water impacts. Floodplain impacts probably would occur if DOE selected the Caliente intermodal transfer station (see Appendix L). If that location was selected, DOE would conduct a detailed floodplain/wetland assessment and integrate good construction practices to minimize impacts. Construction probably would involve some permanent drainage alterations. Runoff rates would differ from natural or existing terrain but, given the relatively small size of the area, there would be little effect on overall runoff quantities for the area (Chapter 6, Section 6.3.3.1; DOE 1998m, pages 4-13 and 5-8). DOE expects very small impacts to surface waters during the construction and operation of the stations.

Groundwater

Construction activities for the intermodal transfer stations would disturb and loosen the ground for some time, which could result in higher infiltration rates. However, these activities and their resultant short-term impacts probably would occur at different times for the three stations. The relatively small sizes of the three facilities would minimize changes in groundwater infiltration rates during operations. Potential sources of contamination would include one to three diesel fuel tanks for the standby generators and heavy equipment for all three stations. The small overall water demand could be met by installing wells or by existing water distribution systems. In addition, the operation of the Apex copper concentrate and DOE low-level radioactive waste intermodal transfer station would only overlap with the beginning years of spent nuclear fuel and high-level radioactive waste shipment to the proposed Yucca Mountain Repository.

8.4.2.4 Biological Resources and Soils

The proposed locations of the intermodal transfer stations are in an irrigated pasture area that is partly wetland. However, because the area was modified as pasture and the native habitat has been degraded, cumulative impacts to biological resources would be low. Construction activities could lead to soil erosion. Water would be applied to suppress dust and compact soil. The operation of the stations would have small cumulative impacts on soils. Erosion damage control would be performed as necessary throughout the operational periods.

8.4.2.5 Cultural Resources

Impacts could occur to archaeological, historic, and traditional Native American cultural sites from the construction of the intermodal transfer stations. Cultural resource surveys of this portion of the Meadow Wash Area have identified two archaeological sites in the vicinity of the proposed DOE low-level radioactive waste intermodal site (DOE 1998m, pages 4-13). Neither site falls within the proposed intermodal transfer station areas. DOE would perform special ethnographic studies and archaeological surveys during the engineering design phases and before construction.

8.4.2.6 Socioeconomics

Employment levels for operation of the repository, Apex, and DOE low-level radioactive waste intermodal transfer stations would be 66, 25, and 14 employees, respectively (Chapter 6 and Section 8.1.2.2). Employment associated with the repository and low-level radioactive waste intermodal transfer stations includes operations personnel and truck drivers. Concurrent operations for all three stations would occur over a portion of the entire 24- or 38-year shipping period for the Proposed Action or Inventory Module 1 or 2, respectively. Employment levels would increase gradually to the maximum values listed above and then decrease gradually toward the end of emplacement activities for repository-related workers. Impacts to employment, population, personal income, Gross Regional Product, and state and local government expenditures during station operations would be small for Lincoln County (Chapter 6, Section 6.3.2.2; DOE 1998m, pages 4-14 and 5-9).

The truck traffic in the Caliente area would be increased from the three intermodal transfer stations. The small increase would have a very small impact on U.S. Highway 93, which would be used when entering and leaving the intermodal transfer station access road. U.S. 93 is currently characterized as having light traffic. The period of concurrent truck traffic from the three intermodal transfer stations would also occur only over a portion of the 24- or 38-year shipping duration for the Proposed Action or Inventory Module 1 or 2, respectively.

8.4.2.7 Occupational and Public Health and Safety

The incremental impacts resulting from an increase in radiological risk associated with the intermodal transfer stations for the repository and low-level radioactive waste shipments at Caliente would not result in a substantial cumulative impact. The estimated total collective worker dose from the entire DOE low-level radioactive waste intermodal shipping campaign, including transportation impacts, would be about 4.21 person-rem (DOE 1998m, page 4-10). This dose, added to the total repository intermodal transfer station and rail and heavy-haul truck shipments worker dose of about 530 to 550 person-rem for the Caliente intermodal transfer station for Inventory Module 1 or 2 (Appendix J, Table J-57) would be an increase of less than 3 percent. The population dose associated with low-level radioactive waste shipments by truck from the intermodal transfer station would be 7.55 person-rem for the entire shipping campaign (DOE 1998m, Table C-11, page C-23). This dose, added to the dose from shipments in Nevada that use heavy-haul trucks of 1,400 person-rem over 38 years, would increase the population dose and associated health effects by less than 1 percent.

8.4.2.8 Noise

There would be an increase in noise levels at the Caliente Site from the three intermodal transfer stations and the associated train switching operations and truck traffic. Noise levels would increase during daytime and night hours for rail activities and during daytime hours for truck shipment activities associated with the repository heavy-haul trucks and the DOE low-level radioactive waste trucks. Apex truck shipments would occur once an hour, 24 hours a day. Noise associated with railcar shipments would occur as the railcars were uncoupled from trains and transferred in and out of the stations, which could occur during the day or night. Elevated noise levels would occur during loading and unloading operations and briefly as trucks passed on the highway. Trucks would not travel through Caliente for shipments to either Yucca Mountain or the Nevada Test Site. Overall, the elevation of noise levels associated with rail and truck activity near a level that would cause concern would be unlikely. In addition, due to the location of the intermodal transfer stations in an uninhabited canyon area, noise impacts from rail and truck loading and unloading would be low. Cumulative effects would also be limited because operations at the DOE low-level radioactive waste and Apex intermodal transfer stations would overlap only a portion of the shipping campaign associated with the proposed repository.

8.4.2.9 Aesthetics

The alteration of the landscape immediately surrounding the Class II lands [within about 8 kilometers (5 miles) of the Kershaw-Ryan State Park] could exceed the Class II objective. Class II designation by the Bureau of Land Management could require retention of the existing character of the landscape. However, the area proposed for the intermodal operations has been classified as Class III, which would require partial retention of the existing character of the landscape. The intermodal facilities would not greatly alter the landscape more than the current passing trains and sewage treatment operations. Public exposure would be limited due to obstruction by natural vegetation. Therefore, visual impacts would be very small (DOE 1998m, pages 4-12 and 5-8).

8.4.2.10 Utilities, Energy, and Materials

Electric power lines with adequate capacity are available near the site. Electric power, water supply, and sewage disposal facilities are currently provided to the sewage treatment facility near the proposed location of the intermodal transfer stations (DOE 1998m, page 4-12). Therefore, cumulative impacts to utilities would be small. The quantities of concrete, asphalt, and steel needed to build the intermodal facilities (associated mostly with the repository intermodal transfer station) would be unlikely to affect the regional supply system.

8.4.2.11 Management of Intermodal Transfer Station-Generated Waste and Hazardous Materials

The expected quantities of sanitary waste, small amounts of hazardous waste, and low-level radioactive waste associated with radiological surveys would be unlikely to have large impacts to landfill, treatment, and disposal facilities available for use by this site. Therefore, cumulative impacts for waste management would be small. Only limited quantities of hazardous materials would be needed for station operations, and DOE does not expect these needs to affect the regional supply system (DOE 1998m, pages 4-12, 4-13, and 5-8).

8.4.2.12 Environmental Justice

Because there would be no large cumulative impacts to human health and safety from the construction or operation of the intermodal transfer stations, there would be no disproportionately high and adverse impacts to minority and low-income populations. The absence of large cumulative environmental impacts for the general population means that there would be no disproportionately high and adverse environmental impacts for the minority or low-income communities. An evaluation of subsistence lifestyles and cultural values confirms these general conclusions. The foregoing conclusions and evaluations and the commitment by DOE to ensure minimal impacts to cultural resources show that construction and operation of the intermodal transfer stations would not be expected to cause or contribute to disproportionately high and adverse impacts to Native Americans (DOE 1998m; pages 4-14 and 5-9).

8.5 Cumulative Manufacturing Impacts

This section describes potential cumulative environmental impacts from the manufacturing of the disposal containers and shipping casks required to emplace Inventory Module 1 or 2 in the proposed Yucca Mountain Repository. No adverse cumulative impacts from other Federal, non-Federal, or private actions have been identified because no actions have been identified that, when combined with the Proposed Action or Inventory Module 1 or 2, would exceed the capacity of existing manufacturing facilities.

The overall approach and analytical methods and the baseline data used for the evaluation of cumulative manufacturing impacts for Inventory Module 1 or 2 were the same as those discussed in Section 4.1.14 for the Proposed Action. The evaluation focused on ways in which the manufacturing of the disposal containers and shipping casks could affect environmental resources at a representative manufacturing site and potential impacts to material sources and supplies.

Table 8-61 lists the total number of disposal containers and shipping casks required for the Proposed Action and Inventory Modules 1 and 2. As listed, the total number would increase by approximately 70 to 80 percent for Modules 1 and 2 in comparison to the Proposed Action. The highest total number of disposal containers and shipping casks would be for the Module 2 disposable canister packaging scenario, and this was the number used in the cumulative impact analysis. The number of disposal containers and shipping casks would not vary with the thermal load scenarios.

Table 8-61. Number of disposal containers and shipping casks required for the Proposed Action and Inventory Modules 1 and 2.

	Proposed Action			Module 1			Module 2		
Components	UC[a]	DISP[b]	DPC[c]	UC	DISP	DPC	UC	DISP	DPC
Disposal containers[d]	10,000	11,000	10,000	17,000	20,000	17,000	18,000	20,000	18,000
Shipping casks[e,f]									
Legal-weight truck	119	11	11	241	17	17	241	17	17
Railcar	0	98	98	0	175	175	0	195	175

a. UC = uncanistered packaging scenario.
b. DISP = disposable canister packaging scenario.
c. DPC = dual-purpose canister packaging scenario.
d. Source: TRW (1999c, all).
e. Shipping casks include transportation overpacks.
f. Sources: Chapter 4, Section 4.2; House (1999, all).

Based on the total number of disposal containers and shipping casks that would be required over a 38-year period for Inventory Module 1 or 2, the annual manufacturing rate would increase about 33 percent over that for the Proposed Action. Thus, the annual Module 1 or 2 impacts for air quality, socioeconomics, material use, and waste generation would be less than 20 percent higher than those discussed in Section 4.2 for the Proposed Action, and these impacts would continue for 38 years rather than the 24 years for the Proposed Action. The total number of worker injuries and illness or fatalities would increase in proportion to the increase in disposal containers and shipping casks manufactured. The potential number of injuries and illnesses over the 38-year period for Module 1 or 2 would be about 500 and the estimated number of fatalities would be 0.24 (that is, no expected fatalities). As for the Proposed Action, there would be few or no impacts on other resources because existing manufacturing facilities would meet the projected manufacturing needs and new construction would not be necessary and environmental justice impacts (that is, disproportionately high and adverse impacts to minority or low-income populations) would be unlikely.

9

Management Actions to Mitigate the Potential for Environmental Impacts

9. MANAGEMENT ACTIONS TO MITIGATE POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

This chapter describes management actions that the U.S. Department of Energy (DOE) would consider using to reduce or mitigate adverse impacts to the environment that could occur if the Department implemented the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. In keeping with previous chapters in this environmental impact statement (EIS), this chapter contains separate discussions for the mitigation of repository impacts and the mitigation of impacts from transportation activities. Under the regulations of the National Environmental Policy Act (40 CFR Section 1508.20), mitigation includes activities that (1) avoid the impact altogether by not taking a certain action or parts of an action; (2) minimize impacts by limiting the degree or magnitude of the action and its implementation; (3) repair, rehabilitate, or restore the affected environment; (4) reduce or eliminate impacts over time by preservation or maintenance operations during the life of the action; or (5) compensate for the impact by replacing or substituting resources or environments.

Apart from the considerations required under the National Environmental Policy Act, Section 116(c) of the Nuclear Waste Policy Act, as amended (NWPA) states that "the Secretary shall provide financial and technical assistance to (an affected unit of local government or the State of Nevada)... to mitigate the impact on such (an affected unit of local government or the State of Nevada) of the development of (a) repository and the characterization of (the Yucca Mountain) site." Such assistance can be given to mitigate likely "economic, social, public health and safety, and environmental impacts." Within that broad framework, neither Section 116 nor any other provision of the NWPA limits the impacts that are subject to assistance under Section 116 to the environmental impacts considered in this EIS.

Under the NWPA, the Section 116 impact assistance review process and the Yucca Mountain Repository EIS process are distinct from one another, and the implementation of one is not dependent on the implementation of the other. Thus, the provision of assistance under Section 116 would not necessarily be limited either by the impacts identified in this EIS or by its findings on such impacts. Any decision to provide assistance under Section 116 will be based on an evaluation of a report submitted by an affected unit of local government or the State of Nevada pursuant to Section 116 to document likely economic, social, public health and safety, and environmental impacts.

9.1 Types of Management Actions

The design, construction, operation and monitoring, and closure planning for the proposed repository incorporate physical features, procedures, and safeguards to reduce environmental consequences. Some of these features, procedures, and safeguards are the result of DOE determinations based on site characterization activities and the ongoing evaluation of planning and design for the proposed repository. To complement the measures already incorporated, DOE is considering a range of additional mitigation measures aimed at reducing effects of the proposed repository project. The repository and transportation mitigation analyses in this chapter discuss impact reduction measures that DOE has committed to implement as well as other mitigations DOE is evaluating for inclusion.

9.1.1 DOE-DETERMINED IMPACT REDUCTION FEATURES, PROCEDURES, AND SAFEGUARDS

DOE has studied the Yucca Mountain site, vicinity, and regions of influence for more than a decade and has accumulated considerable knowledge. The Department has identified many improvements in its project design and plan to reduce potential impacts. The Proposed Action includes commitments to

reduce impacts that DOE has made as a result of its site characterization studies and the ongoing evaluation of repository planning and design. This chapter identifies these commitments in appropriate areas.

9.1.2 MITIGATION MEASURES UNDER CONSIDERATION FOR INCLUSION IN PROJECT PLAN AND DESIGN

Although DOE has conducted extensive site characterization studies, it continues to evaluate whether to commit to additional mitigation measures in the event the U.S. Nuclear Regulatory Commission grants a license for the repository project. DOE is considering these additional measures to reduce the potential effects of the repository project. This chapter identifies measures under consideration in appropriate subject areas.

9.1.3 ONGOING STUDIES THAT COULD INFLUENCE MITIGATION MEASURES IN THE PROJECT PLAN AND DESIGN

Accelerator Transmutation of Waste technology has been under consideration for many years as a process for the treatment of nuclear waste. This technology would involve the use of a chemical separation process, a linear accelerator, and a subcritical nuclear assembly. The chemical process would separate transuranic and certain long-lived radioisotopes from the spent nuclear fuel. The linear accelerator and subcritical nuclear assembly would change the transuranic and long-lived radioisotopes into short-lived radioisotopes and stable (nonradioactive) elements.

The National Research Council studied Accelerator Transmutation of Waste and other technologies for use in the treatment of spent nuclear fuel (National Research Council 1996, all). The study concluded that:

- The use of separation and transmutation to treat spent nuclear fuel is technically feasible.
- Treatment would cost many tens of billions of dollars and require many decades to implement.
- While other technologies would be based on considerable experience, Accelerator Transmutation of Waste technology would require extensive development before DOE could realistically assess its technical feasibility.
- No separation and transmutation technology offers sufficient promise to abandon current spent nuclear fuel management programs or delay the opening of the first nuclear waste repository.
- Even with a successful separation and transmutation program, a monitored geologic repository would still be necessary because the process would be unlikely to provide perfect transmutation, in which case there would be residual materials requiring long-term isolation from human populations and concentrations of human activity.
- Separation and transmutation technology might delay or eliminate the need for a second repository, but there are legislative and less expensive technical ways to increase the capacity of the first repository by an equivalent amount.

In the Fiscal Year 1999 Energy and Water Appropriation Act, Congress directed DOE to conduct an Accelerator Transmutation of Waste study and to prepare a plan for the development of this technology in Fiscal Year 1999. The plan is to address the following:

- The technical issues to be resolved
- A proposed time schedule and program to resolve the technical issues
- The estimated cost of the program
- Consideration of and proposals for collaborative efforts with other countries and programs developing this technology
- The institutional challenges of an Accelerator Transmutation of Waste program
- The impact this technology could have on the civilian spent nuclear fuel program
- Areas of development that could provide benefits to other ongoing programs
- The estimated capital and operational life-cycle costs to treat civilian spent nuclear fuel

The elimination or reduction of certain radionuclides in the disposal inventory could add flexibility to the design of the repository and reduce uncertainties about its performance. DOE will incorporate information from the ongoing study and from any future studies in its decisions during the preparation of the Final EIS and a Mitigation Action Plan for this EIS, if one becomes necessary.

9.2 Yucca Mountain Repository

This section discusses mitigation measures DOE has determined it would implement, or has identified for consideration, to reduce potential impacts from the construction, operation and monitoring, and eventual closure of the proposed repository.

9.2.1 AIR QUALITY

Construction and operation activities such as vehicle movement, clearing, grading, rock pile maintenance, and excavating could generate substantial quantities of fugitive dust. Standard mitigation measures could reduce dust emissions from fugitive dust-generating activities at the Yucca Mountain site. Other dust-generating sources such as operation of the concrete batch plant and backfill preparation facilities would be comparatively small contributors. DOE expects concentrations of other criteria pollutants to be less than 1 percent of regulatory limits (see Chapter 4, Section 4.1.2). Activities that would generate other criteria pollutants include the operation of internal combustion engines in construction equipment, boiler operation, and similar devices, along with limited emissions of radionuclides.

Air Quality Measures Under the Proposed Action

- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (Cowherd, Muleski, and Kinsey 1988, page 5-22).

- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

9.2.2 HYDROLOGY

This section describes potential mitigation measures for surface water and groundwater.

9.2.2.1 Surface Water

Potential impacts to surface water from the construction, operation and monitoring, and eventual closure of the proposed repository would fall into the following categories: (1) introduction of contaminants, (2) alteration of drainage either by changing infiltration and runoff rates or channel courses, and (3) flood hazards. Changes in infiltration and runoff rates could alter flow rates in channels, cause ponding, and increase erosion. DOE expects such impacts to be minimal (see Chapter 4, Section 4.1.3). Nevertheless, the mitigation of impacts could produce such benefits as erosion control and pollution prevention.

Flash floods could spread contamination from accidental spills. Design and operational controls could mitigate the potential for contamination of surface water from accidental releases of radiological or hazardous constituents. DOE's intent would be to respond rapidly with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.

- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood, and by designing facilities that would manage radiological materials to withstand the calculated probable maximum flood.

- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion and runoff control features such as proper placement of pipe, grading, and use of rip-rap at these intersections to enhance the effectiveness of the bridges or culverts.

- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.

- In and near floodplains, follow reclamation guidelines (DOE 1995g, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.

- Implement best management practices, including training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.

- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

Surface-Water Measures Under Consideration

- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.

- Use control measures such as the installation of hay bales and fabric fences to trap sediments moved by runoff.

9.2.2.2 Groundwater

Impacts to groundwater from the proposed repository could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce such impacts for the active life of the repository and the alteration of infiltration and runoff rates would be identical to those described above for surface-water impacts.

The purpose of proposing a monitored geologic repository is to provide a natural setting that, with engineered repository and waste package barriers, would provide long-term confinement and isolation of spent nuclear fuel and high-level radioactive waste. Two aspects of groundwater analysis—(1) the ability of the repository and the engineered barriers to keep waste packages isolated from groundwater over time, and (2) the extent to which groundwater could become contaminated with radionuclides from breached waste packages and transport radionuclides to places where human exposure could occur—are central elements in determining the potential for a proposed repository to succeed. The selection of a potential site with favorable characteristics is a fundamental impact reduction measure.

DOE's detailed study of the Yucca Mountain site has resulted in the inclusion of many engineered barrier elements to complement the site's natural characteristics to keep unsaturated zone groundwater from reaching and transporting radionuclides and, thereby, to reduce the long-term potential for impacts. The following summarizes the engineered barrier elements that would contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository.

Groundwater Measures Under the Proposed Action

- The Yucca Mountain site has several characteristics (as described in Chapter 3) that indicate a high potential for reducing possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste, including:

  - The Yucca Mountain vicinity is isolated from concentrations of human population and human activity and is likely to remain so.

  - The climate is arid and conducive to evapotranspiration, resulting in a relatively small volume of water that has the capability to move as groundwater within the unsaturated zone of the mountain.

  - The groundwater table is substantially below the level at which DOE would locate a repository, providing additional separation from materials emplaced in waste packages.

  - The sparsely populated hydrogeologic basin into which groundwater from Yucca Mountain flows is closed, providing a barrier to a general spread of radionuclides in the event waste packages were breached and radionuclides reached groundwater.

- Use performance confirmation measures to detect any departure from expected capability of the repository in confining and isolating waste.

- Recycle water collected in subsurface areas for use in dust suppression and other activities, to minimize water consumption.

- Implement measures to minimize the potential for water used during operations to interfere with waste isolation in the repository.

- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.

- Use resistant waste packages and other engineered barriers to prevent water intrusion.

- Monitor to detect and define unanticipated spills, releases, or similar events.

- Evaluate thermal load scenarios to minimize the potential for different heat levels to have a direct effect on corrosion rates and the integrity of containers, as well as on the hydrology, geochemistry, and stability of the drifts. Thermal load could indirectly affect general groundwater flow and the transport of radionuclides.

- Use stainless-steel-lined concrete basins that include leak detection systems, pool cleanup equipment, and transfer equipment capable of moving waste in the event of a leak, and that are designed to seismic standards to minimize the potential for leaks in fuel transfer and holding pools located inside surface facilities.

Groundwater Measures Under Consideration

- Use drip shields to deflect water migrating downward through the unsaturated zone to waste storage areas.

9.2.3 BIOLOGICAL RESOURCES AND SOILS

Potential impacts to biological resources and soils from repository construction, operation and monitoring, and closure could result from land clearing, vehicle movement, materials placement, trenching and excavation, and accidents. This section discusses the potential mitigation of impacts that could affect the desert tortoise and biological resources and soils in general.

9.2.3.1 Desert Tortoise

The desert tortoise is the only Federally protected species that resides on the site of the proposed repository (see Chapter 3, biology sections). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat. DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (Buchanan 1997, pages 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (TRW 1998h, page 9) indicates that 27 of 28 tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of the five killed by traffic.

The final biological opinion on site characterization (Buchanan 1997, pages 19 to 25) identified the following actions as requirements that DOE would need to implement to minimize impacts on desert tortoises:

- Alignment and final siting of facilities, construction roadways, cleared areas, laydown areas, and similar elements of construction activity can avoid sensitive areas, lessen the likelihood of entrapment of tortoises, and minimize the fragmentation of known desert tortoise habitat.

- Measures to control erosion, dust, and particulate matter would lessen consequences of repository construction, operation and monitoring, and closure for desert tortoises. Similarly, approaches to minimize soil compaction and crushing of vegetation would lessen consequences for desert tortoises.

- Clearance surveys for desert tortoises before vegetation removal or soil disturbances of more than about 2 hectares (5 acres).

- Removal of tortoises or tortoise eggs found in areas to be disturbed, and tortoises in immediate danger along roads or near ongoing activities to safe nearby locations, with project activity ceasing until removal occurred.

- Prohibitions against driving vehicles off existing roads in nonemergency situations unless authorized. All workers at Yucca Mountain would participate in a required tortoise education program.

- A litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles following the end of each workday, and disposal of trash in a designated sanitary landfill.

- Revegetation of project areas no longer required.

- Construction and maintenance of tortoise-proof fencing to lessen the potential for endangerment to desert tortoises from project-related activities.

- Placement of escape ramps in trenches and inspection of trenches before filling.

If the proposed project proceeds, the Fish and Wildlife Service would establish conditions for repository construction, operation and monitoring, and eventual closure that DOE would have to observe to protect the desert tortoise. DOE and the Fish and Wildlife Service have not completed the consultation process on potential impacts to the desert tortoise, so the Fish and Wildlife Service has not yet established those conditions. DOE would implement terms and conditions set out in any future biological opinions on the desert tortoise. As discussed in Chapter 4, the proposed repository location is at the extreme northern edge of the range of the desert tortoise, and the population of tortoises at that location is small in relation to other portions of its range. No part of the repository location has been declared critical habitat for the desert tortoise.

The following text discusses potential measures DOE has identified for the protection of the desert tortoise based on determinations the Fish and Wildlife Service made for site characterization.

Desert Tortoise Measures Under the Proposed Action

DOE will adopt all reasonable and prudent impact reduction measures to protect the desert tortoise that are stated in any future biological opinions on the Proposed Action.

Desert Tortoise Measures Under Consideration

- Align and locate facilities, roadways, and cleared areas and place appropriate signs to lessen the likelihood of trapping tortoises and to minimize habitat fragmentation.

- Minimize soil compaction and vegetation crushing.

- Ensure through purification or fencing that evaporation pond water is safe for tortoises.

- Conduct surveys for desert tortoises before any habitat disturbance of more than 4,000 square meters (1 acre). The reasons for the limitation on size of land surveyed are that the desert tortoise density across the site is low and surveys of smaller areas are biologically and economically inefficient.

- Move desert tortoises or desert tortoise eggs from areas to be disturbed, from roadways, and from proximity to ongoing activities to safe nearby locations; stop project activity until completion of these actions.

- Require authorization for nonemergency offroad vehicle travel.

- Ensure that all workers on the Yucca Mountain Project participate in a tortoise education program.

- Establish a litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles at the end of each workday, and disposal of trash in a designated sanitary landfill located away from desert tortoise habitat in order to avoid attracting potential predators.

- Revegetate project areas no longer required for the Proposed Action.

- Post road signs to remind drivers of the presence of desert tortoises and other animals, and enforce speed limits.

- Construct and maintain tortoise-proof fencing around actively used construction and operation sites to lessen the potential for danger from project-related activities.

- Provide escape ramps from trenches; inspect trenches before filling them.

9.2.3.2 General Biological Resources and Soils

Impacts to biological resources at the Yucca Mountain site could include habitat fragmentation, loss of individual members of different species, and encroachment of noxious weeds.

Potential soil impacts or concerns related to the proposed repository can be categorized as (1) increased soil erosion rates, (2) slow recovery rate of disturbed soils in the Yucca Mountain environment, and (3) introduction of contaminants. Erosion could result in the loss of the thin topsoil from the disturbed areas, which could affect long-term recovery, be a threat to structures in the region, and result in increased depositions downhill.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.1 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from repository construction, operation and monitoring, and closure.

- Use dust suppression measures on disturbed areas to minimize erosion and aid recovery by reducing wind erosion and supporting compaction.

- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.

- Consider measures to relocate sensitive species in floodplains.

- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.

- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.

- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.2.2.1).

- To aid recovery, strip and stockpile topsoil from disturbed areas (excavated rock pile, etc.). When the disturbed areas are no longer needed, spread the topsoil over the areas and reseed the soil to improve the success of vegetation reestablishment and prevent encroachment of noxious weeds.

- Provide escape ramps from ponds and basins.

9.2.4 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources at Yucca Mountain include those required by law or regulation and those that DOE determined the project would include to reduce such impacts. In some cases, precise mitigation measures cannot be identified due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, programmatic mitigation measures that comply with historic preservation laws and regulations are in place to ensure that DOE would implement appropriate measures following the identification and evaluation of important cultural resources.

The *Programmatic Agreement Between the United States Department of Energy and the Advisory Council on Historic Preservation for the Nuclear Waste Deep Geologic Repository Program, Yucca Mountain, Nevada* (DOE 1988b, all) contains the requirements and general procedures for the mitigation of adverse effects at important archaeological and historic sites in the Yucca Mountain region. The *Research Design and Data Recovery Plan for the Yucca Mountain Project Permanent Copy* (DOE 1990, all) outlines more detailed approaches and procedures for implementing the mitigation of impacts to archaeological sites. Along with other topics, that document provides specific guidelines for

determining the rationale, methods, analytical requirements, and logistics for archaeological mitigation measures at Yucca Mountain. In addition, the Department would consult affected Native American tribes and organizations to ensure that repository activities avoided or minimized adverse impacts to resources or places that are important to Native Americans.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (AIWS 1998, pages 1-1, 2-3, and B-1 *et seq.*). Examples of suggested mitigations include incorporating the assistance of Native American people, continued protection of archaeological sites, funding Native American studies on impacts to natural resources and impacts from transportation (AIWS 1999, pages 4-8 to 4-12).

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the reclamation potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of roads or rail lines would not be reasonable, develop additional mitigation measures.

9.2.5 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

There would be a potential for repository workers to receive doses from exposure to radiation during the operation and monitoring and closure phases of repository activities (Chapter 4, Sections 4.1.7 and 4.1.8).

Erionite and cristobalite are hazardous materials that occur naturally in the Yucca Mountain subsurface. Erionite occurs in strata at varying depths below the planned level of the repository. DOE is mapping these strata as part of a general approach that emphasizes avoidance of erionite. If erionite was encountered during drilling, DOE would shut down the affected portion of its operation until it could put proper controls in place.

Cristobalite, which occurs generally in the subsurface rock structure, could be released during excavation operations or in fugitive dust from the excavated rock pile. There would be a potential for cristobalite to be an inhalation hazard to workers. Implementing specific health and safety plans to prevent worker exposure would minimize risks. Chapter 4, Section 4.1.7, discusses erionite and cristobalite.

After closure, there would be potential for human intrusion that could result in release of radioactive materials.

Occupational and Public Health and Safety Measures Under the Proposed Action

- Avoid erionite-bearing strata where practicable during repository construction.
- If drilling encounters erionite, close operations in potentially affected areas until proper controls are in place.
- Use high-efficiency particulate air filters or similar controls if drilling occurs in an area where there is potential for encountering erionite.
- Design repository construction procedures to reduce the risk of worker inhalation of cristobalite.
- Specify features of ventilation systems and other underground equipment to ensure the elimination of opportunities for occupational exposure to health and safety hazards.
- Use ventilation, planned transfer of cristobalite from work areas, and scrubbing of in-place dust to minimize exposure. Use monitoring devices and respirators as appropriate.
- Use ventilation to keep radon levels low in subsurface areas. Use higher ventilation rates and shorter air travel paths to reduce worker exposure to radon.
- Unload, handle, and package spent nuclear fuel and high-level radioactive waste remotely in hot cells or under water.
- Design task procedures to reduce the potential for accidents.
- Implement health and safety procedures to minimize risks to construction and operations workers.

9.2.6 UTILITIES, ENERGY, AND MATERIALS

A monitored repository at Yucca Mountain would require a range of utility services, energy to power a variety of activities, and a number of diverse materials. DOE intends to promote efficiency in the use of utilities, energy, and materials.

Utility, Energy, and Materials Measures Under the Proposed Action

- Implement procedures and equipment that would minimize the use of utility services, energy, and materials.

Utility, Energy, and Materials Measures Under Consideration

- Construct and operate a 3-megawatt solar electric generating facility to reduce demand on the regional power system.

9.2.7 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

As part of the repository design, DOE would institute a waste minimization program similar to the waste minimization and pollution prevention awareness plan successfully implemented during site characterization activities to minimize quantities of generated waste and to prevent pollution (DOE 1997h, all). In addition, DOE would consider innovations to augment the existing program. The Department could keep the size of the Restricted (for radiological control) Area as small as possible, and it could implement programs to ensure that construction and operation activities used, as practicable, smaller quantities of products such as solvents and cleaners. The design of the proposed repository would

incorporate pollution prevention measures and would provide cradle-to-grave waste management, as DOE provided during site characterization.

Waste and Hazardous Materials Measures Under the Proposed Action

- Recycle wastewater to reduce the amount of water needed for repository facilities and the amount of wastewater that could require disposal (DOE 1997l, page 14).

- Use practical, state-of-the-art decontamination techniques such as recycling the aqueous low-level radioactive waste stream in the Waste Treatment Building. Use techniques such as pelletized solid carbon dioxide blasting that would reduce waste generation in comparison with other techniques (DOE 1997l, pages 9-13 and 9-14).

- Institute preventive maintenance and inventory management programs to minimize waste from breakdowns and overstocking (TRW 1999a, page 55).

- Whenever practicable, recycle nonradioactive materials such as paper, plastic, glass, nonferrous metals, steel, fluorescent bulbs, shipping containers, oils, and lubricants rather than dispose of them (TRW 1999a, pages 62 and 70). Encourage the reuse of materials and the use of recycled materials.

Waste and Hazardous Materials Measures Under Consideration

- Avoid use of hazardous materials where feasible.

9.2.8 LONG-TERM REPOSITORY PERFORMANCE

DOE proposes a repository at Yucca Mountain to provide for permanent disposal of spent nuclear fuel and high-level radioactive waste. DOE's proposal includes a natural geologic setting that, with engineered repository and waste package barriers, would provide long-term isolation of contaminants. In its design process, DOE is considering many features and approaches to contain and isolate the contaminants it proposes to place in the repository.

DOE's detailed study of the Yucca Mountain site and vicinity has resulted in the evaluation of three categories of potential measures: barriers to limit the release and transport of radionuclides, measures to control heat and moisture in the confined environment of the repository, and measures to improve operational efficiency or safety. Each of these measures has the potential to complement the site's natural characteristics. These measures are conceptual in nature, (that is, they have not been developed or analyzed in detail). The following summarizes elements under consideration that could contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository. Appendix E discusses these measures in more detail. Appendix E, Section E.3, discusses enhanced design alternatives, which are various combinations and refinements of the measures described in this section.

Long-Term Performance Measures Under the Proposed Action

DOE has designed an engineered barrier system that would complement the geologic and hydrologic properties of Yucca Mountain to isolate radionuclides in spent nuclear fuel and high-level radioactive waste from accessible portions of the environment. DOE would make use of these engineered features to:

- Locate emplacement areas approximately 300 meters (980 feet) below the surface and approximately 300 meters above the water table.

- Use two-layer waste packages designed to remain intact for thousands of years (at a minimum), with layers that would fail only from different mechanisms and at different rates.

- Encapsulate spent nuclear fuel (normally in zirconium-alloy cladding) and immobilize high-level radioactive waste (normally in borosilicate glass or ceramic matrices) in the waste packages.

- Use steel and concrete supports to hold waste packages off the floors of emplacement drifts.

- Use heat generated from the decay of radioactive material to heat the surrounding rock for 3,000 to 4,000 years to drive water and gas away from the emplaced waste packages.

Long-Term Performance Measures Under Consideration

1. *Barriers to Limit Release and Transport of Radionuclides.* The most direct method to provide the long-term isolation of contaminants is to use structures and techniques that have the potential to inhibit directly the release of contaminants from waste packages or to reduce the likelihood of the transport of released contaminants from the repository. DOE is considering a range of barrier measures that could enhance resistance to corrosion, delay or reduce water transport, retard radionuclide movement and release rates, and reduce the potential for damage to canisters. The Department will continue to evaluate the potential benefits and consequences of these measures together with their compatibility with overall repository system design. The following list contains 10 barrier measures:

   - Ceramic coatings on the exterior of the waste package – Could increase waste package life and repository waste isolation performance by reducing corrosion of the waste package surface and delaying the release of radionuclides.

   - Drip shields – Would provide a partial barrier to divert infiltrating water away from waste packages in an emplacement drift.

   - Backfill in the waste emplacement drifts – Would provide protection to waste packages and drip shields from rockfall and could provide protection against corrosion of the waste packages.

   - Waste package corrosion resistant barrier (metal or ceramic) – Would replace the corrosion-allowance barrier in the reference design with a second corrosion-resistant barrier, promoting longer waste package lifetimes and potentially leading to improved long-term waste isolation performance for the repository.

   - Richards barrier – Would involve placing a coarse-grained, sand-sized material and then a fine-grained, sand-sized material over emplaced waste packages at closure, potentially delaying the transport of water to the waste packages, retarding waste package corrosion, and improving long-term repository performance.

   - Diffusive barrier under waste packages – Loose, dry, granular material placed in the space between each waste package and the bottom of the emplacement drift to form a restrictive barrier to seepage, potentially slowing fluid and radionuclide movement to the natural environment.

   - Getter under waste package – Placing a fine-grained material [either phosphate rock (apatite) or iron oxide (hematite, geothite, etc.] with an affinity for sorption of radionuclides in the recess below waste packages prior to waste emplacement could improve long-term waste isolation through retardation of radionuclide movement from the repository drifts.

   - Canistered assemblies and waste-specific disposal containers – Placing spent fuel assemblies in canisters at the Waste Handling Building before inserting them into waste packages could provide

an additional barrier and further limit mobilization of radionuclides if the waste package was breached.

- Additives and fillers – Placing materials (for example, oxides of iron and aluminum) into waste packages (in addition to those normally required for the basket material) to fill the basket and waste form void spaces could improve both the long-term repository performance (by retarding of release of radionuclides to the groundwater) and the long-term criticality control.

- Ground support options – Placing an engineered system into repository drifts to ensure drift stability before closure could both enhance safety during emplacement and potential retrieval and improve long-term repository performance by reducing or delaying damage to canisters from rockfall (damaged areas are locations for enhanced corrosion even if the canister is not breached by the rockfall).

2. *Measures to Control Heat and Moisture in the Repository Environment.* Long-term influence over heat and moisture in the repository environment could increase the ability of the waste packages to isolate waste. DOE is evaluating measures that have the potential to control temperature and humidity levels in the repository to reduce corrosion rates, increase structural and support system stability, and increase the capability to retain released radionuclides in the repository. The Department will continue to examine the potential for enhancements in repository performance offered by these measures, other consequences of implementing them, and their compatibility with overall repository system design. DOE is considering the 11 items listed below:

- Tailored waste package spatial distribution – Tailoring spatial distribution of the waste packages within the repository block according to waste package heat production, or the tendency of radionuclides in different packages to travel, resulting in a more uniform temperature across the repository. This would improve the performance of waste packages by delaying and reducing contact of water and/or increasing sorption of released radionuclides by zeolites in the unsaturated zone, thereby potentially improving repository waste isolation performance.

- Low thermal load alternative evaluation (similar to the 25-MTHM-per-acre thermal load option evaluated in this EIS) – Increasing repository ventilation rates, increasing the spacing between waste packages or drifts, or reducing the size of waste packages and maintaining reference design spacing could reduce uncertainties regarding elevated temperature of the host rock and could potentially reduce waste package material corrosion rates.

- Continuous post-closure ventilation design – Continuous ventilation of the emplacement drifts during the postclosure period could increase removal of moisture from air around the waste packages for a period of time (though moisture would eventually reestablish itself), and it could improve performance by retarding waste package corrosion.

- Preemplacement aging and blending of spent nuclear fuel and high-level radioactive waste could provide thermal performance benefits for the proposed repository. Aging would reduce the total thermal energy that the repository must accommodate, and blending would reduce the variability in the distribution of the thermal energy in the repository drifts. Potential benefits are improved rock stability and retardation of waste package degradation.

- Continuous preclosure ventilation – Continuous ventilation in the emplacement drifts before repository closure would reduce rock wall and air temperatures and remove moisture to reduce corrosion rates and increase the stability of the ground support system.

- Drift diameter – A smaller diameter drift would be more stable (less rockfall potential), could reduce seepage into the drifts, and could reduce the need for ground support systems, while a larger diameter drift would allow for other modes of emplacement, such as horizontal or vertical borehole emplacement.

- Waste package spacing and drift spacing – Emplacing waste packages nearly end-to-end [that is, with a 0.1-meter (0.3-foot)-gap] with no consideration of individual waste package characteristics would provide a more intense and uniform heat source along the length of emplacement, requiring an increase in emplacement drift spacing and, potentially, continuous ventilation of emplacement drifts, but also would keep emplacement drifts hot and dry for a longer period, decrease the amount of water that could contact waste packages, and reduce the number of emplacement drifts needed for waste emplacement.

- Near-field rock treatment during construction – Filling cracks in a portion of the rock above each emplacement drift with grout to reduce or retard water seepage into the drifts after closure of the repository.

- Surface modification (alluvium) – Covering the surface of Yucca Mountain above the repository footprint with alluvium (soil) could decrease the net infiltration of precipitation water into the repository.

- Surface modification (drainage) – Removing the thin alluvium layer over the footprint of the repository would promote rapid runoff of surface water, potentially reducing infiltration from the top and improving long-term isolation of the waste.

- Higher thermal loading – Higher thermal loading than the 85 MTHM per acre analyzed in this EIS would keep the drift temperature above the boiling point for a longer period, thereby minimizing the amount of moisture around the waste packages for a longer postclosure period, but it potentially would have adverse effects on the surrounding rock.

3. *Repository Designs to Support Operational Considerations.* Including elements in the design that would enhance the repository's operational capabilities could improve access to waste packages after their emplacement, increase access for conducting performance confirmation, inspection, and maintenance activities, ease any effort to augment the repository system with later-developed materials or processes, and facilitate retrieval of waste packages if retrieval became necessary. DOE is considering measures that could provide additional shielding for personnel, increase usable space in drifts, increase opportunities for monitoring, and reduce the potential for moisture to contact waste packages. The Department will continue to assess the potential for design modifications to assist operational activities within the context of overall repository system design. DOE is considering six potential design modification measures:

   - Enhanced access design – Additional shielding around the waste package would allow for personnel accessibility during waste package loading, transfer to the drift, emplacement, and performance confirmation, permitting personnel to carry out performance confirmation activities, offering increased access for maintenance and ease of operations, and potentially eliminating some remote handling equipment.

   - Modified waste emplacement mode design – Emplacing unshielded waste packages in configurations where the repository's natural or engineered barriers provide shielding (for example, in boreholes drilled into the floor or wall of emplacement drifts, in alcoves off the emplacement drifts, in trenches at the bottom of the emplacement drift, or in short cross drifts

excavated between pairs of excavated drifts) would enhance human access, improve performance confirmation efficiency, and facilitate inspections and ground support.

- Rod consolidation – Rod consolidation would involve bringing fuel rods into close contact with one another, allowing the capacity of waste packages to be increased and/or the size of waste packages to be reduced, potentially reducing the size or number of waste packages and, if consolidation were accomplished at the reactor sites, possibly reducing waste transportation shipments.

- Timing of repository closure – Extending the period before final closure, together with a maintenance program to accommodate an extended long-term repository service life and ground support components designed and maintained for a service life of up to 300 years, would allow for reduction of waste package heat output after closure, extended monitoring before closure, and an extended retrieval period for the waste.

- Waste package self shielding – Adding a shielding material on the outside of waste packages would reduce the radiation in the drifts to levels such that personnel access would be possible.

- Repository horizon – A two-level repository would increase repository capacity without moving out of the characterized area. It would increase thermal load to reduce the amount of water that could come in contact with waste packages; add flexibility in emplacing waste packages on the lower level, which could be shielded from moisture infiltration by the upper level; and potentially facilitate retrieval due to the ability to operate two independent retrieval operations at the same time.

9.3 Transportation

This section discusses mitigation measures DOE is required to implement, has determined to implement, or has identified for consideration, to reduce potential impacts from the national transportation of spent nuclear fuel and high-level radioactive waste. These measures address impacts from the possible construction of a branch rail line or an intermodal transfer station in Nevada; construction of other transportation routes; upgrading of existing Nevada highways to accommodate heavy-haul vehicles; transportation of spent nuclear fuel and high-level radioactive waste from existing storage sites to the proposed repository; and fabrication of casks and canisters.

9.3.1 LAND USE

Mitigation measures could address three types of potential land-use impacts resulting from the construction and operation of a rail line or an intermodal transfer station: (1) impacts to publicly used lands such as grazing allotments, (2) direct and indirect land loss, and (3) displacement of capital improvements. Mitigation would not necessarily be associated with the potential selection of a route for heavy-haul trucks, which would follow existing rights-of-way and would require little additional land disturbance.

Land Use Measures Under the Proposed Action

- Ensure that construction activities were consistent with best management practices, by:

  - Ensuring that the location selection and final route alignment for a branch rail line or location selection for an intermodal transfer station consider (1) the minimum impacts to private lands, capital improvements, floodplains or wetlands, areas containing cultural resources, or other environmentally sensitive areas, and (2) indirect loss of land (the division of property or limitation of access) such as the use of grazing allotments.

  - Minimizing the size and number of easements.

  - During the rail construction phase, locating construction camps and staging areas along the rail line in consultation with parties controlling the surrounding lands.

  - Reclaiming disturbed areas outside the permanent right-of-way as soon as practicable after completion of construction.

9.3.2 AIR QUALITY

If DOE selected the Valley Modified rail corridor, mitigation measures could be needed to reduce fugitive dust emissions from rail line construction and carbon monoxide emissions from operations in the Las Vegas nonattainment area. As described in Chapter 6, Section 6.3.2.2.5, fugitive dust emissions during the construction phase could be above the General Conformity Rule *de minimis* levels for particulates. Vehicles used to transport workers and trains used to transport materials would generate criteria pollutants. States could place requirements for control of emissions of volatile organic compounds and nitrous oxide on facilities that manufacture containers and casks.

Air Quality Measures Under Consideration

- Use buses to transport workers, reducing nitrogen oxide and hydrocarbon emissions.

- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (Cowherd, Muleski, and Kinsey 1988, page 5-22).

- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

9.3.3 HYDROLOGY

This section describes potential mitigation actions for both surface water and groundwater.

9.3.3.1 Surface Water

Three categories of potential impacts to surface water from the construction and operation of a Nevada transportation route are (1) the introduction of contaminants, (2) the alteration of drainage patterns or runoff rates, and (3) flood hazards. The spread of contamination by surface water could result in adverse impacts to plants and animals or to human health in the immediate area. It could also result in the

recharge of contaminated water to groundwater. DOE's intent is to respond rapidly to such spills with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.
- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood.
- Minimize the potential for contamination spread or other physical impacts to surface water by avoiding spills in unconfined areas and areas subject to flash floods, where practicable, and by locating the alignment of a branch rail line or heavy-haul road to avoid floodplains and surface waters, including wetlands, springs, and riparian areas, when possible, and to minimize any potential impacts to these features.
- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.
- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion control features such as proper placement of pipe, revegetation, and use of erosion control at these intersections where practicable to enhance the effectiveness of the bridges or culverts.
- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.
- In and near floodplains, follow reclamation guidelines (DOE 1995g, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.
- Implement best management practices including training employees in the handling, storage, distribution, and use of hazardous materials to provide practical prevention and control of potential contamination sources.
- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.
- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

Surface-Water Measures Under Consideration

- Designate bermed or contained sites outside areas subject to flash flooding for fueling and chemical handling to minimize the potential for contamination spreading if spills occurred.

9.3.3.2 Groundwater

Potential transportation-related impacts to groundwater would be most likely to occur from construction activities associated with a potential Nevada transportation route and could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce impacts would be identical to those described above for surface-water impacts.

Groundwater Measures Under the Proposed Action

- Implement best management practices, such as training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.

Groundwater *Measures Under Consideration*

- Place construction wells only in undesignated basins. (A Designated Groundwater Basin is one in which the quantity of appropriated water approaches or exceeds the perennial yield as *determined* by the Nevada State Engineer.)

- Employ water-use minimization and recycling techniques to reduce water consumption.

9.3.4 BIOLOGICAL RESOURCES AND SOILS

9.3.4.1 Desert Tortoise

The desert tortoise is the only Federally protected species that resides at or along the potential rail corridors, intermodal transfer station locations, and routes for legal-weight and heavy-haul trucks in Nevada (see Chapter 6, Sections 6.3.1, 6.3.2.1, and 6.3.3.1). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat.

DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (Buchanan 1997, pages 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (TRW 1998h, page 9) indicates that 27 of 28 individual tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of the five killed by traffic.

The final biological opinion on site characterization (Buchanan 1997, pages 19 to 25) identified the following actions as requirements that DOE would need to implement to minimize impacts on desert tortoises:

- Alignment and final siting of facilities, construction roadways, cleared areas, laydown areas, and similar elements of construction activity could avoid sensitive areas, lessen the likelihood of entrapment of tortoises, and minimize the fragmentation of known desert tortoise habitat.

- Measures to control erosion, dust, and particulate matter would lessen consequences of repository construction, operation and monitoring, and closure for desert tortoises. Similarly, approaches to minimize soil compaction and crushing of vegetation would lessen consequences for desert tortoises.

- Clearance surveys for desert tortoises before vegetation removal or soil disturbances of more than about 2 hectares (5 acres).

- Removal of tortoises or tortoise eggs found in areas to be disturbed, and tortoises in immediate danger along roads or near ongoing activities to safe nearby locations, with project activity ceasing until removal occurred.

- Prohibitions against driving vehicles off existing roads in nonemergency situations unless authorized. All workers at Yucca Mountain would participate in a required tortoise education program.

- A litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles following the end of each workday, and disposal of trash in a designated sanitary landfill.

- Revegetation of project areas no longer required.

- Construction and maintenance of tortoise-proof fencing to lessen the potential for endangerment to desert tortoises from project-related activities.

- Placement of escape ramps in trenches and inspection of trenches before filling.

If the proposed project proceeded, the Fish and Wildlife Service would establish conditions for repository-related transportation activities that DOE would have to observe to protect the desert tortoise. DOE would implement terms and conditions set out in any future biological opinions on the desert tortoise. As discussed in Chapter 6, areas that would be affected by transportation activities are at the extreme northern edge of the range of the desert tortoise, and the population of tortoises in these areas is low in relation to other portions of its range. No part of the repository location has been declared critical habitat for the desert tortoise.

The following text discusses potential measures DOE has identified for the protection of the desert tortoise based on determinations the Fish and Wildlife Service made for site characterization.

Desert Tortoise Measures Under the Proposed Action

If a consultation process results from a determination that construction or operation of a transportation corridor associated with the proposed repository could affect threatened or endangered species or their habitat, DOE will adopt all reasonable and prudent measures to protect the desert tortoise or other species that are stated in future biological opinions on transportation corridors.

Desert Tortoise Measures Under Consideration

- Align and locate facilities, roadways, and cleared areas and place appropriate signs to lessen the likelihood of trapping tortoises and to minimize habitat fragmentation.

- Minimize soil compaction and vegetation crushing.

- Move desert tortoises or desert tortoise eggs from areas to be disturbed, from roadways, and from proximity to ongoing activities to safe nearby locations; stop project activity until completion of these actions.

- Require authorization for nonemergency offroad vehicle travel.

- Ensure that all workers on the Yucca Mountain Project participate in a tortoise education program.

- Establish a litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles at the end of each workday, and disposal of trash in a designated sanitary landfill located away from desert tortoise habitat in order to avoid attracting potential predators.

- Revegetate project areas no longer required for the Proposed Action.

- Post road signs to remind drivers of the presence of desert tortoises and other animals, and enforce speed limits.

- Construct and maintain tortoise-proof fencing around actively used construction and operation sites to lessen the potential for danger from project-related activities.

- Provide escape ramps from trenches; inspect trenches before filling them.

9.3.4.2 General Biological Resources and Soils

Certain herds of migratory animals could be substantially affected if they were prevented from moving back and forth between ranges at different times of the year. Some of the transportation routes under consideration cross game management areas and wild horse and wild burro management areas. Some routes cross areas traversed by herds of antelope, mule deer, elk, and mountain sheep. Fencing would not be likely to affect the movement of mule deer and elk. Fencing could impede the movements of antelope, mountain sheep, wild horses, and wild burros, effectively dividing management areas for these species.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.1 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from transportation activities.

- Use dust suppression measures on disturbed areas to minimize erosion and aid recovery by reducing wind erosion and supporting compaction.

- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.

- Consider measures to relocate sensitive species in floodplains.

- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.3.3.1).

- Conduct surveys of areas along the transportation corridor selected for construction to locate areas that are potential habitats for sensitive or State-protected species before the beginning of construction activities. Avoid springs, wetlands, waters of the United States, and riparian areas, if possible.

- Reduce habitat fragmentation and barriers to animal movement by considering the needs and movement patterns of mobile species (for example, wild horses) in the design and construction of rail lines, routes, and fencing. Seek input from wildlife agencies and organizations.

- If the construction and operation of a transportation route in Nevada could not avoid springs and wetlands, minimize the amount of disturbance (to the maximum extent possible) by carefully timing construction activities; minimizing corridor widths; locating laydown, excavated rock pile, and fueling areas away from sensitive areas where practicable; and conducting any wetlands replacement activities in accordance with plans approved by the U.S. Army Corps of Engineers.

- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.

- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.

- To aid recovery, strip and stockpile topsoil from disturbed areas (excavated rock pile, etc.). When the disturbed areas are no longer needed, spread the topsoil over the areas and reseed the soil to improve the success of vegetation reestablishment and prevent encroachment of noxious weeds.

9.3.5 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources along transportation routes include those required by law or regulation and those built into the project to reduce such impacts. In some cases, DOE cannot identify precise mitigation measures due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, DOE has programmatic mitigation measures that comply with historic preservation laws and regulations in place to ensure that it would implement appropriate actions after the identification and evaluation of important cultural resources.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (AIWS 1998, page 2-19). AIWS (1998, page 4-1) suggested mitigations such as setting aside important cultural and ceremonial areas, and assisting in revegetation and reclamation activities.

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the reclamation potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation measures.

9.3.6 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

Over time, traffic accidents involving vehicles associated with the proposed repository would occur. The analysis indicated that fatalities and injuries from traffic accidents (nonradiological events) probably would constitute the largest impact to public health associated with the project. (See the Occupational and Public Safety and Health sections in Chapters 4 and 6.)

During the transportation of spent nuclear fuel and high-level radioactive waste, drivers and escort personnel would be routinely exposed to radiation and would receive radiological doses from this exposure. Workers and members of the public could receive doses from exposures resulting from an accident that released radionuclides.

Occupational and Public Health and Safety Measures Under Consideration

- Establish contract requirements to minimize worker exposure to ionizing radiation.
- Improve design of affected roadways to reduce accidents.
- Promote alternative transportation such as buses for workers to reduce automobile accidents.
- Implement a radiation protection plan for drivers and escort personnel.
- Implement accident reduction measures such as the Commercial Vehicle Safety Alliance procedures.

9.3.7 NOISE

Noise impacts could occur along a transportation corridor, depending on the scenario. Native Americans have expressed concern about noise associated with the transportation corridors and the movement of spent nuclear fuel and high-level radioactive waste to the proposed repository (AIWS 1998, page 2-16). Impacts could result from the construction and operation of the facilities associated with transportation. There is concern that transportation activities could disrupt ceremonies that address Native American concerns for ecological health and the solitude needed for healing or prayer. Other communities could be subject to adverse noise levels, depending on the selected route and the potential to reduce such consequences. DOE expects the potential for adverse impacts from noise to be low.

Noise Control Measures Under Consideration

- Avoid areas with sensitive receptors.

- Avoid Native American ceremonial sites.

- Consider noise intensity, time and distance, and noise canceling or interference factors when planning construction activities and facilities.

- If the transportation corridor passes through areas close to sensitive human receptors (schools, institutions, etc.), plan for noise abatement walls to reduce noise levels at specific locations.

- Install equipment that meets decibel limitations (see Chapter 6).

- Schedule vehicle travel through communities during daylight hours.

- Ensure that the receipt and transfer of material from railcars to heavy-haul trucks at an intermodal transfer station occurred during daylight hours.

9.3.8 MANAGEMENT OF WASTE AND HAZARDOUS MATERIALS

The manufacture of casks and containers could produce liquid and solid waste streams that would require disposal.

Waste and Hazardous Materials Measures Under the Proposed Action

- Design construction to include use of materials, such as depleted uranium, that could otherwise require disposal as wastes.
- Recycle lubricating and cutting oils.
- Recycle solid waste components where practicable.
- Employ ion exchange and filtration or similar methods to treat water used for ultrasonic weld testing for reuse in the manufacturing process.

10

Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitment of Resources

10. UNAVOIDABLE ADVERSE IMPACTS; SHORT-TERM USES AND LONG-TERM PRODUCTIVITY; AND IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

This chapter discusses adverse impacts that would remain after the application of mitigation measures (see Chapter 9). It analyzes the relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity, and it identifies irreversible or irretrievable commitments of resources. The chapter presents information drawn from the analysis of the Proposed Action. It summarizes and consolidates information from the impact and mitigation analyses in Chapters 4, 5, 6, and 9, and provides references to earlier chapters for readers who require more detailed information.

The chapter discusses only resource areas for which preceding analyses have identified unavoidable impacts. Nevertheless, the discussions in Sections 10.1, 10.2, and 10.3 reflect an examination of the resource areas analyzed in this EIS.

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that the U.S. Department of Energy (DOE) could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources.

10.1 Unavoidable Adverse Impacts

This section summarizes potential impacts associated with the proposed repository and transportation actions that would be unavoidable and adverse and that would remain after DOE implemented mitigation measures. Chapter 9 discusses mitigation measures. This chapter mentions some but not all mitigation measures. Some aspects and activities discussed in Section 10.1 are analyzed from different perspectives in Sections 10.2 and 10.3.

10.1.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes unavoidable adverse impacts associated with the construction, operation and monitoring, closure, and long-term performance of the proposed repository.

10.1.1.1 Land Use

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of land surrounding the Yucca Mountain site. DOE could obtain permanent control over the land only if Congress completed a land withdrawal action. A Congressional withdrawal would include lands already withdrawn for the Nevada Test Site and Nellis Air Force Range as well as lands under the control of the Bureau of Land Management and not currently withdrawn.

In general, the permanent withdrawal of land for the repository would prevent human use of the withdrawn lands for other purposes. Nevada Test Site activities would continue on a noninterference basis unless the Congressional land withdrawal specifically precluded them. Because the Yucca Mountain site has a low present resource value, is remote, and is partly withdrawn, the resultant impact would be small.

The disposal of spent nuclear fuel and high-level radioactive waste could permanently affect the availability of the surface and subsurface of the Yucca Mountain site. The Chapter 4 land-use discussion includes the availability of the land and the consequences of withdrawal.

10.1.1.2 Air Quality

Construction, operation and monitoring, and closure of a repository at Yucca Mountain would produce very small impacts to regional air quality. Radiological impacts could occur from the release of radionuclides. The principal radionuclides released from the subsurface would be naturally occurring radon-222 and its decay products in ventilation exhaust air. There are no applicable regulatory limits for radon releases from Yucca Mountain facilities. Other impacts would come from criteria pollutants and materials such as cristobalite and erionite. Exposures of maximally exposed individuals to radionuclides and criteria pollutants would be a small fraction of applicable regulatory limits.

10.1.1.3 Hydrology

Construction activities would temporarily restrict and minimally alter natural surface-water drainage channels. Facilities and roadways would be designed to withstand at least a 100-year flood. Therefore, after construction was complete, only flow from infrequent more intense floods would affect those facilities and roadways. Ground-disturbing activities and the surface facilities that DOE would build would alter surface-water infiltration and runoff rates in localized areas. Given the relatively small size of the affected land in comparison to the total drainage area, drainage channels and washes would experience little difference in impacts as a result of the disturbances. DOE estimates that overall consequences from the construction of roadways and facilities would be minimal. Appendix L contains a floodplain/wetlands assessment that examines the effects of branch rail line and highway route construction, operation, and maintenance on floodplains in the vicinity of Yucca Mountain.

There would be withdrawals of groundwater during construction, operations and monitoring, and closure, but they would not exceed estimates of perennial yield. Chapter 4, Section 4.1.3, provides details on the effects of repository construction, operation and monitoring, and closure on hydrology.

In the reference design, waste packages would be placed about 300 meters (1,000 feet) below the mountain surface and about 300 meters above the water table (see Section 5.2). Even if future climates were much wetter than they are today, the mountain would not be likely to erode and leave the waste exposed, and the water table would not be likely to rise high enough to reach the waste.

In the current semiarid climate, about 18 centimeters (7 inches) of water a year from rain and snow fall on Yucca Mountain. Nearly all of that precipitation, about 95 percent, runs off or evaporates. Only about 0.65 centimeter (0.31 inch) of water per year moves down (or percolates) through the nearly 300 meters (1,000 feet) of rock to reach the proposed level of the repository (see Chapter 3, Section 3.1.4).

After waste packages were placed in the repository, the heat generated from radioactive decay would raise the temperature in the drifts above the boiling point of water. The heat should dry the surrounding rock and drive any water away for hundreds to thousands of years. However, as the waste decayed and the repository cooled, some water would begin to seep through fractures in the rock into the drifts and pass through the repository.

Analysts estimate that, after the repository cooled enough, about 5 percent of the packages could experience dripping water under the current climate. If the climate changed to a wetter long-term average, about 30 percent of the packages could experience dripping water. Based on preliminary results of corrosion experiments and the opinions of experts, computer simulations indicated that most waste

packages would last more than 10,000 years, even if water was dripping on them. The longevity of manmade materials in the repository environment over such long periods is subject to considerable uncertainty, however, and some waste packages could fail earlier. Analysts estimated that dripping water could cause the first penetrations—tiny pinholes—to appear in some waste packages after about 4,000 years. More substantial penetrations could begin to occur about 10,000 years later. Analysts also assumed that at least one waste package would fail within 1,000 years due to a manufacturing defect (see Chapter 5, Section 5.4.1).

After water entered a waste package, it would have to penetrate the metal cladding of the spent nuclear fuel to reach the waste. For about 99 percent of the commercial spent nuclear fuel, the cladding is highly corrosion-resistant metal designed to withstand the extreme temperature and radiation environment in the core of an operating nuclear reactor. Current models indicate that it would take thousands of years to corrode cladding sufficiently to allow water to reach the waste and begin to dissolve the radionuclides.

During the thousands of years required for water to reach the waste, the radioactivity of most of the radionuclides would decay to virtually zero. For the remaining radionuclides to get out of the waste package, they would have to dissolve in the water. Few of the remaining radionuclides could dissolve at a meaningful rate. Thus, only long-lived water-soluble radionuclides could get out of the waste package. Long-lived water-soluble radionuclides that migrated from the waste packages would have to move down through about 300 meters (1,000 feet) of rock to the water table and then travel about 20 kilometers (12 miles) to reach a point where they could be taken up in a well and consumed or used to irrigate crops (see Chapter 5, Sections 5.3 and 5.4).

As the long-lived water-soluble radionuclides began to move down through the rock, some would stick (or adsorb) to the minerals in the rock and be delayed in reaching the water table. After reaching the water table, radionuclides would disperse to some extent in the larger volume of groundwater beneath Yucca Mountain, and the concentrations would be diluted. Eventually, groundwater with varying concentrations of different radionuclides would reach locations in the hydrologic (groundwater) region of influence where the water could be consumed.

Of the approximately 200 different radioactive isotopes present in spent nuclear fuel and high-level radioactive waste, nine are present in sufficient quantities and are sufficiently long-lived, soluble, mobile, and hazardous to contribute meaningfully to calculated radiation exposures.

10.1.1.4 Biological Resources and Soils

Unavoidable adverse impacts to biological resources would include the loss of small pieces of habitat totaling less than 2 square kilometers (500 acres). The pieces that would be disturbed are habitat for terrestrial plant and animal species that are widespread throughout the region and typical of the Mojave and Great Basin Deserts. The death or displacement of individuals of some animal species as a result of site clearing and vehicle traffic would be unavoidable; however, changes in the regional population of any species would be minimal and largely undetectable.

No endangered species are found on the site. The only threatened species on the site is the desert tortoise (see Chapter 4, Section 4.1.4). Approximately 2 square kilometers (500 acres) of desert tortoise habitat would be lost. This habitat is at the northern end of the range of the desert tortoise and is not designated critical habitat for the tortoise. The quantity of habitat that could be lost would be minimal in comparison to the range of the desert tortoise. Individual tortoises could be killed inadvertently during site clearing and by vehicle traffic. Preconstruction surveys, relocation of affected individuals, and general adherence to conditions developed in the course of endangered species consultations would minimize, but not prevent, such deaths. Chapter 4, Section 4.1.4, discusses in detail the potential for loss of habitat or the

deaths of individual members of this species. Chapter 9 (Sections 9.2.3 and 9.3.4) discusses mitigation measures to reduce potential impacts to the desert tortoise, including measures to locate facilities and roadways to avoid sensitive areas and measures to protect tortoises from construction impacts.

10.1.1.5 Cultural Resources

In the view of Native Americans, the implementation of the proposed repository and its facilities would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, represent an irreversible impact to traditional lands.

Some unavoidable adverse impacts could occur to archaeological sites and other cultural resources, although no such sites or culturally important artifacts have been found at the site of the proposed repository. There could be a loss of archaeological information due to illicit artifact collection. In addition, excavation activities could cause a loss of archaeological information. Chapter 3, Section 3.1.6, discusses the program DOE has in place to address and mitigate cultural resource impacts and issues. DOE anticipates this program would continue through repository closure.

NATIVE AMERICAN VIEW

A Native American view of facility and transportation route development, especially in remote areas such as Yucca Mountain and its surroundings, as expressed in the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, pages 2-20 and 3-1), is that development of such facilities and routes inherently degrades the entire environment. This view is based on the concept that the earth, its waters, the air, and the sky are a whole and have a sacred integrity in their natural form. Chapter 4, Section 4.1.13, of this EIS presents an environmental justice discussion of this Native American perspective.

10.1.1.6 Occupational and Public Health and Safety

There would be a potential for injuries to or fatalities of workers from facility construction, including accidents and inhalation of cristobalite. Cristobalite is a naturally occurring hazardous material in the rock of Yucca Mountain. Engineering controls and training and safety programs would reduce but not eliminate the potential for injuries or fatalities to workers.

Short-term impacts during the operation and monitoring phase would present a potential for injuries or fatalities to workers from industrial accidents and exposure to radioactive materials. Engineering controls and training and safety programs would reduce but not eliminate the potential. There would also be a potential for injuries and fatalities during closure. The occupational and public health and safety discussion in Chapter 4 (Sections 4.1.7 and 4.1.8) provides details on the potential for worker injuries and fatalities. The potential for injury or death to members of the public from exposure to radioactive materials or industrial activity would be extremely small.

While there would be a potential for radioactive contamination of groundwater during the 10,000-year analysis period from materials stored at the proposed repository, there would be only a small potential for such contamination to produce long-term adverse health impacts in the surrounding region during this period. Potential long-term impacts to human health from the repository in the far future would be dominated by impacts from radioactive materials dissolved or suspended in water pathways. The dose to the maximally exposed individual would depend on the distance from the repository and the uses made of the land and waters.

At the closest distance evaluated [5 kilometers (3 miles)], the highest 95th-percentile annual dose to the maximally exposed individual for the 10,000-year analysis period could be 1.3 millirem per year. The highest chance of a latent cancer fatality to this hypothetical individual would be 4.4 in 100,000 (see Chapter 5, Section 5.4.1). A latent cancer fatality is a cancer fatality that could occur after and as a result of exposure to radionuclides from the repository and that would be in addition to cancer fatalities occurring from all other causes.

Expected doses and consequences to the population from exposure to radionuclides transported by groundwater from the repository were forecast for the 10,000-year analysis period. The 95th-percentile population dose over the 10,000-year period could be 0.032 person-rem over an assumed 70-year lifetime. The estimated 95th-percentile chance that a single latent cancer fatality could occur in the population during any 70-year lifetime would be 1.6 in 100,000. Over the 10,000-year analysis period, the estimated chance that a latent cancer fatality could occur would be 5.3 in 10,000 (see Chapter 5, Section 5.4.1). These consequences would be small.

DOE estimates that most waste packages would remain intact longer than 10,000 years. Current model simulations forecast that some packages would last more than 1 million years. The highest 95th-percentile peak annual dose rate to a hypothetical maximally exposed individual could be 9,100 millirem per year approximately 320,000 years in the future. The highest mean peak annual dose rate to a maximally exposed individual could be 1,400 millirem per year approximately 792,000 years in the future (see Chapter 5, Section 5.4).

There would also be a potential that chromium releases could produce estimated peak concentrations during the first 10,000 years of 0.037 milligram per liter at 5 kilometers (3 miles) (95th-percentile probability). This value is about one-third of the threshold for contamination in drinking water.

10.1.2 NEVADA TRANSPORTATION ACTIONS

This section summarizes unavoidable adverse impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste and with the construction and operation of transportation facilities and routes in Nevada. Chapter 6 (Sections 6.1.2 and 6.3) provides more detailed discussions.

10.1.2.1 Land Use

Constructing and operating a new branch rail line would result in unavoidable changes to present land uses and control of the lands affected directly. The range of potentially affected uses includes grazing, wildlife habitat and management areas, utility corridors, lands leased for oil and gas development, and military lands. Present uses of adjoining lands would be affected only minimally. Each of the five alternative rail alignments encompasses a range of different land uses and surface features. If the choice was to construct a new branch rail line, the selection of a specific corridor would determine the land actually taken and the extent of impacts to land uses along that corridor. Land disturbed for a specific corridor implementing alternative could vary from 5 to 19 square kilometers (1.9 to 7.3 square miles). Most land along the corridors under consideration is government-owned.

Routes for heavy-haul or legal-weight trucks would follow existing highways and would require little additional land disturbance. Building and operating an intermodal transfer station would result in unavoidable changes of land use and ownership. The land for an intermodal transfer station could be public or private. Actual land uses lost would depend on the site selected. DOE expects that the total land disturbance for any implementing alternative for the construction of an intermodal transfer station and construction along existing highways would be 0.2 square kilometer (about 50 acres). For heavy-haul truck routes originating at Caliente, an additional 0.04 square kilometer (10 acres) could be required for a

mid-route stop. For the Caliente heavy-haul truck route only. A further 0.04 square kilometer could be required for the construction of a highway segment near Beatty, Nevada.

In some instances transportation facilities could remain in place to serve other purposes after DOE had ended use. Similarly, affected land could revert to other uses after the end of transportation activities and the removal of facilities.

10.1.2.2 Hydrology

The construction of a branch rail line or the upgrading of roads to accommodate heavy-haul transportation in Nevada would involve the unavoidable adverse impact of altering natural surface-water drainage patterns. Any of the Nevada transportation corridors would cross a number of natural drainage channels. Upgrade activities for a route to be used by heavy-haul trucks would involve the extension of existing drainage control structures as necessary to support the road upgrades. In this case, there would be minor changes to drainage channels already altered to some extent by the original road construction. The construction of a branch rail line would require alterations to many natural drainage areas along the line. Bridges and culverts would be used as necessary to cross streams, creeks, or, most predominantly, washes of any size. These structures would be built to accommodate a 100-year flow in the channels; the resulting drainage alteration would be confined to relatively small areas. Construction could alter small drainage channels or washes more because the railway design could call for the collection of some channels to a single culvert. At the end of the period during which DOE would transport spent nuclear fuel and high-level radioactive waste to the repository, the Department could remove facilities built for transportation and land recovery could begin, or it could use the facilities for other purposes. Appendix L contains a floodplain/wetlands assessment that presents a comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites with their five associated heavy-haul routes.

10.1.2.3 Biological Resources and Soils

Unavoidable adverse impacts to biological resources from transportation in Nevada could occur as a result of habitat loss and the deaths of small numbers of individual members of the species along transportation routes. Habitat loss would be associated with the construction of either a new rail line or an intermodal transfer station and upgrades to existing highways. This loss would occur in widely distributed land cover types, and would include the loss of a small amount of desert tortoise habitat and the deaths of a small number of tortoises. The deaths of individual members of a species as a result of construction activities or from vehicle traffic would be unlikely to produce detectable changes in the regional population of a species.

Transportation route construction or upgrades would subject disturbed soils to increased erosion for at least some of the construction phase. The recovery of these disturbed areas to predisturbance conditions would occur with the passage of time. Transportation facilities such as a branch rail line could be used for nonrepository-related purposes, potentially extending their useful life beyond the period needed for the Proposed Action. The removal of transportation facilities after the end of their useful life would assist habitat recovery.

10.1.2.4 Cultural Resources

Some unavoidable impacts could occur to archaeological sites and other resources as a result of the construction of a rail line or the upgrade of a highway to heavy-haul capability. The potential for impacts to specific resources cannot be identified before final surveys and actual construction. An agreement now in effect between DOE and the Advisory Council on Historic Preservation for repository site

characterization could serve as a model for an agreement to protect archaeological sites and other resources along transportation corridors. In addition, a number of statutes provide protective frameworks (see Chapter 11). Nevertheless, there would be a potential for grading and other construction activities to degrade, cause the removal of, or alter the setting of archaeological sites or other cultural resources. Although mitigated to some extent by worker education programs, there could be some loss of archaeological information due to the illicit collection of artifacts. In addition, excavation activities could cause loss of archaeological information.

10.1.2.5 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the construction and operation of the rail and heavy-haul implementing alternatives would be unavoidable. Table 10-1 presents potential impacts to worker health during construction and the potential for traffic fatalities among the implementing alternatives during operations.

Table 10-1. Unavoidable adverse impacts from rail and heavy-haul truck implementing alternatives.[a]

Implementing alternative	Construction (worker injuries and illnesses)	Operation (traffic fatalities)
Rail		
Caliente	110	0.83
Carlin	100	0.85
Caliente-Chalk Mountain	80	0.81
Jean	68	0.61
Valley Modified	32	0.60
Heavy-haul truck		
Caliente	32	2.7
Caliente-Chalk Mountain	19	2.2
Caliente-Las Vegas	22	2.5
Apex/Dry Lake	13	1.5
Sloan Jean	14	1.6

a. Source: Chapter 6, Sections 6.3.2.1 and 6.3.3.1.

The transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions and through traffic accidents. This EIS evaluates two transportation scenarios—one in which DOE would transport the materials mostly by truck and the other in which it would transport the materials mostly by rail. DOE estimates that the transportation of spent nuclear fuel and high-level radioactive waste in the mostly truck scenario could cause approximately 23 latent cancer fatalities among workers and the public as a result of exposure to radiation and emissions over the course of 24 years. Over the same period, DOE estimates that transportation mostly by rail could cause approximately 4 latent cancer fatalities among workers and the public. In addition, DOE estimates that transportation mostly by truck or mostly by rail could result in approximately 3.9 or 3.7 traffic fatalities, respectively (see Chapter 6, Section 6.2.4.2).

10.2 Relationship Between Short-Term Uses and Long-Term Productivity

The Proposed Action could require short-term uses of the environment that would affect long-term environmental productivity. This section describes possible consequences to long-term productivity from those short-term environmental uses.

The EIS analysis identified two distinct periods for the evaluation of the use of the environment by the Proposed Action:

- A 120- to more than 300-year period for surface activities consisting of construction, operation and monitoring, and closure of the proposed repository. DOE activities during this period would include construction of facilities, receipt and emplacement of spent nuclear fuel and high-level radioactive waste, recovery of recyclable materials, decontamination, closure of surface and subsurface facilities, reclamation of land, and long-term monitoring. Sections 10.1.1.1 through 10.1.1.6 describe the unavoidable impacts that could occur during this period. This period would be the only time during which DOE would actively use the affected lands and the only time during which activities would involve the surface of the land used for the repository.

- The balance of a 10,000-year period would be for the evaluation of consequences from the disposal of spent nuclear fuel and high-level radioactive waste.

In general, transportation and disposal activities associated with the proposed repository would benefit long-term productivity by removing spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites around the country. In addition, removing these materials from existing sites would also free people and resources committed now and in the future –to monitoring and safeguarding these materials for other potentially more productive activities. Removal could create conditions that would enable the initiation of other productive uses at the commercial and DOE sites. Finally, disposing of spent nuclear fuel and high-level radioactive waste in the proposed repository would provide a long-term global benefit by isolating the materials from concentrations of human population and human activity, thereby reducing the potential for sabotage.

10.2.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes the relationship between short-term uses of land and resources and long-term land and resource productivity for the construction, operation and monitoring, closure, and long-term performance of the proposed repository. The terms "short-term" and "long-term" commonly used in National Environmental Policy Act analyses do not have a consistent duration in this section. For the analysis of impacts associated with repository activities, *short-term* refers to the time from the start of construction to the end of relevant surface and subsurface human activity, which DOE anticipates to be a 120- to 300-year period. *Long-term* refers to the time between the end of relevant surface and subsurface human activity and the time when environmental resources have recovered from the potential for impacts and are again productive, or a maximum of 10,000 years. For transportation, *short-term* refers to the time of construction or actual transportation, as appropriate. *Long-term* refers to the time from the end of the short-term period to the time of environmental recovery. *Productivity* refers to the ability of an element of the environment to generate crops, provide habitat, or otherwise serve as a medium for the creation of value.

10.2.1.1 Land Use

From the start of construction through the 10,000-year period, the construction, operation and monitoring, and closure of the proposed repository would deny other users the use of the Yucca Mountain vicinity for other purposes. Chapter 4, Section 4.1.1, discusses the long-term uses of land. Conversely, a repository at Yucca Mountain would enable consideration of other uses for the sites where spent nuclear fuel and high-level radioactive waste are being stored and the land buffering those sites. Many present storage sites are in locations that would permit a wider range of alternative uses than does Yucca Mountain.

10.2.1.2 Hydrology

The proposed repository would be in a terminal basin that is hydrologically isolated and separated from other bodies of surface and subsurface water; that is, once water enters the basin it can leave only by evapotranspiration. As noted in Section 10.1.1.3, there would be a potential for materials disposed of at the proposed Yucca Mountain Repository to reach groundwater at some time between several thousand years and several hundred thousand years. If such contamination reached groundwater in the accessible environment, and if the groundwater contamination exceeded applicable regulatory requirements, there could be an attendant loss of productivity for the affected groundwater and for surface waters in the basin that the groundwater supplied. Conversely, the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would free a wide range of major and minor water bodies throughout the United States from the potential threat of radioactive contamination from the materials at the present storage sites.

10.2.1.3 Biological Resources and Soils

Short-term uses that could cause impacts to biological resources and soils would be associated with the construction, operation and monitoring, and closure of the repository; those activities could lead to long-term productivity loss in disturbed areas. This loss would be limited to less than 2 square kilometers (500 acres) of widely distributed habitats adjacent to existing disturbed areas. Biological resources would be affected directly by land disturbances. The overall impact to populations of species would be limited because the area disturbed and the number of individual animals lost would be small in relation to the regional availability.

Long-term productivity loss for soils would be limited to areas affected by land disturbances. These areas would be revegetated after the completion of closure activities. Revegetation would be accomplished through the reclamation of disturbed sites using surface soils stockpiled during construction, reseeding, and similar activities that would enhance recovery. Chapter 4, Section 4.1.4, contains more detail on productivity losses and reclamation. The disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would remove these materials from proximity to biota near the present storage sites across the United States.

10.2.1.4 Occupational and Public Health and Safety

A repository at Yucca Mountain would be likely to have a positive effect on the nationwide general occupational and public health because of the cessation of doses to workers at the present storage sites and because the spent nuclear fuel and high-level radioactive waste would be substantially more isolated from concentrations of people and from pathways to concentrations of people.

10.2.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station and improvements to existing highways, all short-term uses, could lead to a long-term loss of productivity in disturbed areas along the routes. In the context of transportation, *long-term* refers to the period of environmental recovery after the end of the construction period or the active use of a transportation route for repository purposes. A route could be used for repository purposes from 10 to approximately 30 years.

The land cover types along any route are widely distributed in the region. A loss of vegetation from a disturbed area along a route would have little effect on the regional productivity of plants and animals.

Productivity loss for soils would be limited to areas affected by land clearing and construction. These areas would not be available for revegetation and habitat for some time. Disturbed areas would recover, however, and eventually would return to predisturbance conditions, although the process of recovery would be slow in the arid environment. Chapter 6 contains more data on transportation.

The construction of a rail line, if the line were also used for nonrepository uses, could result in productivity benefits for Nevada by increasing transportation opportunities, lowering transportation costs, reducing accidents, and lowering nitrogen oxides, carbon monoxide, and other gaseous criteria pollutant emissions by diverting transportation from highway to rail.

The major long-term consequence of transporting spent nuclear fuel and high-level radioactive waste to the repository would be the permanent consolidation of these materials in an isolated location away from concentrations of people and without exposure pathways to concentrations of people.

10.3 Irreversible or Irretrievable Commitment of Resources

The Proposed Action would involve the irreversible or irretrievable commitment of land, energy, and materials. The commitment of a resource is irreversible if its primary or secondary impacts limit future options for the resource. An irretrievable commitment refers to the use or consumption of resources that are neither renewable nor recoverable for later use by future generations. Construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain would result in a permanent commitment of land, groundwater, surface, subsurface, mineral, biological, soil, and air resources; materials such as steel and concrete; and consume energy in forms such as gasoline, diesel fuel, and electricity. Water use would support construction, operation and monitoring, and closure actions, and options for using groundwater could become limited if there was contamination from radionuclides. There would be an irreversible and irretrievable commitment of associated natural resource services such as uses of land and habitat productivity.

10.3.1 YUCCA MOUNTAIN REPOSITORY

The construction, operation and monitoring, closure, and long-term performance of the Yucca Mountain Repository would result in the permanent commitment of the surface and subsurface of Yucca Mountain and the permanent withdrawal of lands from public use. Because of the remote location of Yucca Mountain, the lack of present uses of the land, the terminal and isolated nature of the water basin, and the limited amounts of materials and energy required for the repository in comparison to the supply capability of the regional and national economies, the irreversible and irretrievable commitments of resources for repository-related activities would be small.

Mitigation approaches that would involve the excavation of archaeological sites to prevent degradation by construction activities would destroy the contexts of those sites and reduce the finite number of such resources in the region. DOE expects that its activities at the proposed repository would affect no more than a minimal number of such sites. The Department would use state-of-the-art mitigation techniques on the Yucca Mountain Project.

Electric power, fossil fuels, and construction materials would be irreversibly committed to the project. Most of the steel used for the surface facilities would be recyclable and, therefore, not an irreversible or irretrievable commitment. Some copper and steel in the ramps and access mains to subsurface facilities would be recyclable, while some in the emplacement drifts would be irreversibly and irretrievably lost. Some steel, such as rebar, would be difficult to recycle. The quantity of resources consumed would be small in comparison to their national consumption or their availability to consumers in southern Nevada.

These quantities are described in Chapter 4. To the extent that there is value in spent nuclear fuel or high-level radioactive waste, that value would be committed to the repository.

Aggregate would be crushed as required and mixed in concrete for the cast-in-place and precast concrete structures and liners that would be used in the repository. The amount of sand and aggregate could range from 500,000 to 1.5 million metric tons (550,000 to 1.7 million tons). If Yucca Mountain tuff was used, the amount crushed and used as sand and aggregate would be about 10 percent of the total excavated from the drifts (see Chapter 4, Section 4.1.11).

10.3.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station would result in an irretrievable but not irreversible commitment of resources. Many resources could be retrieved at a later date through such actions as removing roadbeds, revegetating land, and recycling materials. Land uses would change along the selected transportation corridor during repository construction, operation and monitoring, and closure, thereby limiting or eliminating other land uses for that period. At the end of that period, however, land along the corridor could revert to public or private ownership.

Mitigation approaches involving the recovery of archaeological resources before construction activities degraded the sites would reduce the finite number of such resources in the Yucca Mountain region and destroy the context of sites. DOE would use state-of-the-art mitigation techniques during the construction of a rail corridor or an intermodal transfer station or the modification of roadways to accommodate heavy-haul trucks. Heavy-haul construction would be likely to generate only minimal impacts to cultural resources because construction would largely involve modifications to existing roads.

DOE would use about 500 to 700 million liters (132 to 185 million gallons) of fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository. The analysis in Chapter 6 (Sections 6.1.2.10, 6.3, 6.3.2.1, 6.3.2.2, 6.3.3.1, and 6.3.3.2), evaluates fuel use for the different transportation scenarios. The amount used would be a very small fraction of a percent of the Nation's supply over the period of fuel use.

The manufacture of casks and containers would require commitment of aluminum, chromium, copper, depleted uranium, lead, molybdenum, nickel, and steel. The required amounts of these materials, expressed as percentages of U.S. production, would be low with the exception of nickel, which would require approximately 8.2 percent of annual U.S. production.

11

Statutory and Other Applicable Regulations

11. STATUTORY AND OTHER APPLICABLE REQUIREMENTS

The U.S. Department of Energy (DOE) has conducted site characterization activities in accordance with requirements of applicable laws and regulations and a range of permits and approvals that regulate the various aspects of the activities. The Department has successfully met environmental protection standards for its site characterization activities by developing a comprehensive approach to environmental compliance that ensures adherence to Federal and state requirements. It has implemented specific environmental compliance programs for pollution prevention, protection of cultural resources, and protection of threatened or endangered species. In its future actions involving Yucca Mountain, DOE will continue to comply with applicable Federal and state environmental requirements and with the conditions of the permits and approvals that might be required to conduct its activities.

This chapter identifies major requirements that could be applicable to the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. Section 11.1 lists statutory and regulatory provisions that set requirements potentially applicable to siting a monitored geologic repository. Section 11.2 summarizes statutes and regulations that set environmental protection requirements that could apply to a repository at Yucca Mountain. Section 11.3 contains a list of DOE Orders that could apply to activities related to the proposed repository. Section 11.4 contains a list of potentially applicable requirements compiled by the DOE Office of Civilian Radioactive Waste Management.

Table 11-1 lists potential new permits, licenses, and approvals that DOE could need for construction, operation, and closure of the Yucca Mountain Repository.

11.1 Statutes and Regulations Establishing or Affecting Authority To Propose, License, and Develop a Monitored Geologic Repository

Nuclear Waste Policy Act of 1982, as amended (42 USC 10101-10270)

The Nuclear Waste Policy Act, as amended in 1987 (called the NWPA), directs DOE to characterize and evaluate the suitability of only Yucca Mountain in southern Nevada as a potential site for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. After considering the suitability of the site and other information, the Secretary may then recommend approval of the site to the President. Further, the NWPA directs that this Site Recommendation would constitute a major Federal action and that an EIS must accompany a recommendation that the President approve the site for a repository. In accordance with the NWPA, the Secretary of Energy must submit an application for construction authorization to the U.S. Nuclear Regulatory Commission within 90 days of the effective date of a Presidential designation of Yucca Mountain as a site for a repository.

The NWPA directs the U.S. Environmental Protection Agency to promulgate generally applicable standards for protection of the environment from offsite releases from radioactive material in repositories. In addition, it requires the Nuclear Regulatory Commission to consider and approve or disapprove an application (if DOE submits one) for authorization to construct a repository for these materials based on Commission standards, which are to be consistent with the Environmental Protection Agency standards. In 1983, the Nuclear Regulatory Commission promulgated licensing requirements (10 CFR Part 60) that contain criteria governing the issuance of a construction authorization and license for a geologic repository (see Table 11-1, item 1). These requirements would allow DOE to develop a repository for the receipt and disposal of spent nuclear fuel and high-level radioactive waste and would establish conditions under which DOE could receive and possess source, special nuclear, and byproduct

Table 11-1. Permits, licenses, and approvals needed for a monitored geologic repository.

	Activity	Regulatory action	Statute or regulation	Agency(ies)
1.	Repository construction, operation, and closure	Construction authorization, license to operate and monitor, and license for closure	10 CFR[a] Part 60	Nuclear Regulatory Commission
2.	Repository construction, operation, and closure	Authorization to Withdraw Land From Public Use	43 CFR Part 2300	Congress, Bureau of Land Management
3.	Air emissions	Approvals for New Sources of Toxic Air Pollutants	40 CFR Parts 61 and 63	Environmental Protection Agency
			NAC 445B.287 *et seq.*[b]	Nevada Division of Environmental Protection
4.	Air emissions	Air Quality Operating Permit	NAC 445B.287 *et seq.*	Nevada Division of Environmental Protection
5.	Air emissions	National Emission Standards for Hazardous Air Pollutants Subpart H (Radionuclides)	40 CFR Part 61	Environmental Protection Agency
			10 CFR Part 20	Nuclear Regulatory Commission
		National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Environmental Protection Agency
6.	Certification of facilities	Certification of Air and Water Pollution Control Facilities	40 CFR Part 20	Environmental Protection Agency
7.	Drinking water	Water System Operating Permit	NAC Section 445A	Nevada Health Division
8.	Effluents	Stormwater Discharge	40 CFR Part 122	Environmental Protection Agency
			NAC 445.070 *et seq.*	Nevada Division of Water Planning
9.	Effluents	National Pollutant Discharge Elimination System	40 CFR Part 122	Environmental Protection Agency
		State Water Pollution Control Permit	NAC Section 445A	Nevada Division of Water Planning, Nevada Division of Environmental Protection
10.	Excavation; facility construction	Cultural Resource Review Clearance, Section 106 Agreement	36 CFR Part 800	Advisory Council on Historic Preservation, State Historic Preservation Officer
11.	Excavation; facility construction	Permit to Proceed (Objects of Antiquity)	36 CFR Part 296 43 CFR Parts 3 and 7	Department of the Interior
12.	Excavation; facility construction	Permit for Excavation or Removal of Archaeological Resources	16 USC 470 *et seq*	Department of the Interior, affected Native American Tribes
13.	Facility construction	Free-Use Permit	43 CFR Part 3600	Bureau of Land Management, Forest Service
14.	Facility construction	Permit for the discharge of dredged or fill materials to Waters of the United States	Clean Water Act, Section 404	U.S. Army Corps of Engineers
15.	Facility construction	Right-of-way reservation	43 CFR 2800	Bureau of Land Management
16.	Facility construction and operation	Endangered Species Consultation	50 CFR 402.6	Fish and Wildlife Service
17.	Materials storage	Hazardous Materials Storage Permit	NAC Sections 459 and 477	Nevada State Fire Marshal

a. CFR = Code of Federal Regulations.
b. NAC = Nevada Administrative Code.

material at a geologic repository. The requirements in 10 CFR Part 60 do not apply to any nonrepository activities licensed under other parts of Title 10 of the Code of Federal Regulations.

Congress originally passed the Nuclear Waste Policy Act in 1982. The original legislation directed the Secretary of Energy to recommend potential sites to the President for possible characterization as geologic repositories, and it directed the President to select sites for characterization. The original Nuclear Waste Policy Act also required the Secretary of Energy to issue general guidelines for use in recommending potential geologic repository sites for detailed site characterization. DOE issued those guidelines in 1984 (10 CFR Part 960) and applied them when it nominated five sites as suitable for characterization and recommended characterization of three of the sites.

DOE also decided to include in the general guidelines a process for evaluating the data obtained from site characterization activities to be used in determining whether a site should be recommended for the development of a geologic repository. In 1996, DOE proposed amendments to the general guidelines to establish a site-specific standard for evaluating the suitability of the Yucca Mountain site for possible recommendation for development as a repository. DOE has not issued final amendments. In the Site Recommendation, if any, DOE will consider the guidelines applicable at that time.

Section 116(c) of the NWPA establishes a procedure by which DOE can consider and, if appropriate, address a broad array of considerations. The State of Nevada or an affected unit of local government can describe impacts that are likely to result from site characterization in a report and submit it to the Secretary of Energy. Section 116 of the NWPA allows DOE to consider these impacts as a basis for DOE providing technical or financial assistance. In contrast to the National Environmental Policy Act process, a Section 116(c) determination of impact assistance is not tied to an extensive body of past precedent or regulatory interpretations. DOE has broad discretion under Section 116(c) to consider impacts that the State of Nevada or an affected unit of local government might identify.

Energy Policy Act of 1992 (42 USC 10101 *et seq.*)

The Nuclear Waste Policy Act of 1982 directed the Environmental Protection Agency to establish standards to protect the general environment from offsite releases of radioactive materials from repositories, and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress passed the Energy Policy Act, modifying the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission with respect to a potential repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency (1) to retain the National Academy of Sciences to make findings and recommendations on reasonable public health and safety standards for Yucca Mountain, and (2) to establish Yucca Mountain-specific standards based on and consistent with these findings and recommendations. The standards are to set health-based limits for any radioactive releases from a repository at Yucca Mountain. The DOE repository design must meet Nuclear Regulatory Commission requirements for demonstrating compliance with the Environmental Protection Agency standards.

The National Academy of Sciences issued its findings and recommendations in a 1995 report (National Research Council 1995, all). When the Environmental Protection Agency establishes its final standards, it will place them in the Code of Federal Regulations, probably at 40 CFR Part 197.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the site-specific Yucca Mountain standard established by the Environmental Protection Agency. In February 1999, the Nuclear Regulatory Commission issued draft site-specific technical requirements and criteria (proposed 10 CFR Part 63). When finalized, the Commission would use these requirements and criteria in their final forms to approve or disapprove an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel at such a repository, and to close and decommission such a repository.

National Environmental Policy Act of 1969, as amended (42 USC 4321 *et seq.*)

The National Environmental Policy Act requires agencies of the Federal Government to prepare environmental impact statements (EISs) on potential impacts of proposed major Federal actions that may significantly affect the quality of the human environment.

DOE has prepared this EIS in accordance with the requirements of the National Environmental Policy Act as implemented by Council on Environmental Quality regulations (40 CFR Parts 1500 through 1508) and DOE National Environmental Policy Act regulations (10 CFR Part 1021), and in conformance with the NWPA.

Atomic Energy Act of 1954, as amended (42 USC 2011 *et seq.*)

The Atomic Energy Act, as amended, provides fundamental jurisdictional authority to DOE and the Nuclear Regulatory Commission over governmental and commercial use of nuclear materials. The Atomic Energy Act ensures proper management, production, possession, and use of radioactive materials. It provides DOE the authority to develop generally applicable standards for protecting the environment from radioactive materials. In accordance with the Atomic Energy Act, DOE has established a system of requirements that it has issued as DOE Orders.

The Atomic Energy Act gives the Nuclear Regulatory Commission specific authority to regulate the possession, transfer, storage, and disposal of nuclear materials, as well as aspects of transportation packaging design requirements for radioactive materials, including testing for packaging certification. Commission regulations applicable to the transportation of radioactive materials (10 CFR Parts 71 and 73) require that shipping casks meet specified performance criteria under both normal transport and hypothetical accident conditions.

Federal Land Policy and Management Act of 1976 (43 USC 1701 *et seq.*)

The Federal Land Policy and Management Act governs the use of Federal lands administered by the Bureau of Land Management, which is an agency of the U.S. Department of the Interior. Access to and use of public lands administered by the Bureau are primarily governed by the regulations regarding the establishment of rights-of-way (43 CFR Part 2800) and withdrawals of public domain land from public use (43 CFR Part 2300) (see Table 11-1, item 2), as described below in this section.

Some implementing alternative branch rail lines, routes for heavy-haul trucks, and intermodal transfer station locations that could be involved in transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would cross or occupy land administered by the Bureau of Land Management and would require right-of-way reservations (see Table 11-1, item 14). DOE has obtained right-of-way reservations from the Bureau of Land Management and a concurrence from the U.S. Air Force for access to the Yucca Mountain vicinity for characterization activities.

To develop a monitored geologic repository at Yucca Mountain, DOE would need to obtain control of Bureau of Land Management, Air Force, and DOE lands in western Nevada. Land withdrawal is the method by which the Federal Government gives exclusive control of land it owns to a particular agency for a particular purpose. Nuclear Regulatory Commission licensing conditions for a repository include a requirement that DOE either own or have permanent control of lands for which it is seeking a repository license, and that lands used for a repository be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

The Federal Land Policy and Management Act, by which the Government accomplishes most Federal land withdrawals, contains a detailed procedure for application, review, and study by the Bureau of Land

Management, and decisions by the Secretary of the Interior on withdrawal and on the terms and conditions of withdrawal. Withdrawals accomplished through the Federal Land Policy and Management Act remain valid for no more than 20 years and, therefore, do not appear to meet the permanency of control required by the Nuclear Regulatory Commission.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal.

Executive Order 11514, *National Environmental Policy Act, Protection and Enhancement of Environmental Quality*

Executive Order 11514 directs Federal agencies to monitor and control their activities continually to protect and enhance the quality of the environment. The Order also requires the development of procedures both to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs with potential environmental impacts, and to obtain the views of interested parties. DOE has promulgated regulations (10 CFR Part 1021, *National Environmental Policy Act Implementing Procedures*) and has issued a DOE Order (451.1A, *National Environmental Policy Act Compliance Program*) to ensure compliance with this Executive Order.

11.2 Statutes, Regulations, and Orders Regarding Environmental Protection Requirements

11.2.1 AIR QUALITY

Clean Air Act, as amended (42 USC 7401 *et seq.*)

The Clean Air Act is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Act requires Federal agencies such as DOE, with jurisdiction over any property or facility that might result in the discharge of air pollutants, to comply with "all Federal, state, interstate, and local requirements" related to the control and abatement of air pollution.

The Clean Air Act requires the Environmental Protection Agency to establish National Ambient Air Quality Standards to protect public health, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 USC 7409). It also requires the establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants (42 USC 7411) and the evaluation of specific emission increases to prevent a significant deterioration in air quality (42 USC 7470). In addition, the Clean Air Act regulates emissions of hazardous air pollutants, including radionuclides, through the National Emission Standards for Hazardous Air Pollutants Program (40 CFR Parts 61 and 63). Air emission standards are established at 40 CFR Parts 50 through 99.

Nevada Revised Statutes: Air Emission Controls, Chapter 445B

These statutes and regulations in the Nevada Administrative Code implement State and Federal Clean Air Act provisions, identify the requirements for permits for each air pollution source (unless it is specifically exempted), and identify ongoing monitoring requirements. In accordance with the Clean Air Act, DOE could have to obtain an Operating Permit from the Nevada Division of Environmental Protection for the control of gaseous, liquid, and particulate emissions associated with the construction and operation of a repository at Yucca Mountain (see Table 11-1, item 4). To ensure that its site

characterization activities comply with applicable Clean Air Act and State provisions, DOE has obtained an operating permit for surface disturbances and point source emissions.

11.2.2 WATER QUALITY

Safe Drinking Water Act, as amended [42 USC 300(f) *et seq.*]

The primary objective of the Safe Drinking Water Act is to protect the quality of public water supplies. This law grants the Environmental Protection Agency the authority to protect the quality of public drinking water supplies by establishing national primary drinking water regulations. In accordance with the Safe Drinking Water Act, the Environmental Protection Agency has delegated authority for enforcement of drinking water standards to the states. Regulations (40 CFR Parts 123, 141, 145, 147, and 149) specify maximum contaminant levels, including those for radioactivity, in public water systems, which are generally defined as systems that serve at least 15 service connections or regularly serve at least 25 year-round residents.

The Safe Drinking Water Act also authorizes the Environmental Protection Agency to regulate the underground injection of waste and other contaminants into wells. The Agency has codified its regulations at 40 CFR Part 144. The Proposed Action would not constitute underground injection.

In 1978, the Environmental Protection Agency approved the Nevada program for enforcing drinking water standards. The Nevada Health Division is responsible for enforcement of these standards. The proposed repository would include a drinking water system that obtained water from a source off the repository site, and DOE would operate the system in accordance with Nevada Health Division permitting requirements, if applicable (see Table 11-1, item 6).

Clean Water Act of 1977 (33 USC 1251 *et seq.*)

The purpose of the Clean Water Act, which amended the Federal Water Pollution Control Act, is to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The State of Nevada has been delegated the authority to implement and enforce most programs in the State under the Clean Water Act; exceptions include those addressed by Section 404, which is administered by the U.S. Army Corps of Engineers, as described below in this section.

The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Act generally requires all departments and agencies of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements. Under the Clean Water Act, states generally set water quality standards, and the Environmental Protection Agency and states regulate and issue permits for point-source discharges as part of the National Pollutant Discharge Elimination System permitting program. The Environmental Protection Agency regulations for this program are codified at 40 CFR Part 122, and Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. If the construction or operation of a Yucca Mountain Project facility or associated transportation route in Nevada would result in point-source discharges, DOE could need to obtain a National Pollutant Discharge Elimination System permit from the State of Nevada Division of Environmental Protection (see Table 11-1, item 8).

Sections 401 and 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act. Section 402(p) requires the Environmental Protection Agency to establish regulations for the Agency or individual states to issue permits for stormwater discharges associated with industrial activity, including construction activities that could disturb 5 or more acres (40 CFR Part 122). Nevada rules for this

program are codified at Nevada Administrative Code Chapter 445A. The Agency has promulgated regulations implementing a separate stormwater permit application process.

Section 404 of the Clean Water Act gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill material into waters of the United States. DOE could need to obtain a permit from the Corps for activities associated with a repository at Yucca Mountain if those activities would discharge dredge or fill into any such waters. If the construction or modification of rail lines or highways to the repository included dredge or fill activities or other actions that would discharge dredge or fill into waters of the United States, those activities would also require Section 404 permits. DOE has obtained a Section 404 permit for site characterization-related construction activities it might conduct in Coyote Wash or its tributaries or in Fortymile Wash.

Nevada Revised Statutes: Water Controls, Chapter 445A

These statutes classify the waters of the State, establish standards for the quality of all waters in the State, and specify permitting and notification provisions for stormwater discharges and for other discharges to waters of the State in accordance with provisions of the Federal Clean Water Act. These statutes and regulations in the Nevada Administrative Code also (1) set drinking water standards, specifications for certification, and conditions for issuance of variances and exemptions, (2) set standards and requirements for the construction of wells and other water supply systems, (3) establish the different classes of wells and aquifer exemptions, and (4) establish requirements for well operation and monitoring, plugging, and abandonment activities. Regardless of whether these provisions are applicable, DOE has obtained an Underground Injection Control Permit and a Public Water System Permit for site characterization activities at Yucca Mountain. The Underground Injection Control Permit covers tracers, pump tests, and similar activities. The Public Water System Permit establishes the terms for the provision of potable water.

The Department would install and operate the drinking water system planned for the proposed repository in accordance with Nevada Health Division standards, if applicable, and could obtain a Water System Operating Permit from the Nevada Health Division (see Table 11-1, item 6). DOE could need to obtain a General Permit for Storm Water Discharge from the Nevada Division of Water Resources to construct and operate a repository at Yucca Mountain (see Table 11-1, item 7). Any point-source discharges to waters of the State that occurred in the course of Yucca Mountain Project activities could require a National Pollutant Discharge Elimination System permit issued under these provisions. Regardless of whether these provisions are applicable, DOE has obtained a general discharge permit from the State for effluent discharges to the ground surface during site characterization.

Nevada Revised Statutes: Underground Water and Wells, Chapter 534

These statutes and regulations in the Nevada Administrative Code establish the ownership of underground waters in the State and their appropriation for beneficial use. The regulations also establish licensing requirements for well drillers; requirements for drilling, construction, and plugging of wells; and protection of aquifers from pollution and waste. Regardless of whether these provisions are applicable, DOE has obtained a permit for the use of underground water from several wells during site characterization, and it could apply for additional or expanded authority under these provisions, if needed and applicable.

Executive Order 11988, *Floodplain Management*

This Order directs Federal agencies to establish procedures to ensure that any Federal action undertaken in a floodplain considers the potential effects of flood hazards and floodplain management and avoids floodplain impacts to the extent practicable. For its site characterization activities, DOE conducted a

floodplain assessment (see Appendix L) in accordance with this Order (DOE 1992b, all) and DOE implementing regulations (10 CFR Part 1022).

Compliance With Floodplain/Wetlands Environmental Review Requirements (10 CFR Part 1022)

Federal regulations (10 CFR Part 1022) establish policy and procedures for implementing Executive Order 11988, *Floodplain Management*, and for discharging DOE responsibilities regarding the consideration of floodplain/wetlands factors in DOE planning and decisionmaking. These regulations also establish DOE procedures for identifying proposed actions located in floodplains, providing opportunity for early public review of such proposed actions, preparing floodplain assessments, and issuing statements of findings for actions in a floodplain. The rules apply to all DOE proposed floodplain actions.

If DOE determines that an action it proposes would take place wholly or partly in a floodplain, it is required to prepare a notice of floodplain involvement and a floodplain assessment containing a project description, a discussion of floodplain effects, alternatives, and mitigations. For a proposed floodplain action for which a National Environmental Policy Act document such as an environmental impact statement or an environmental assessment is required, DOE is to include the floodplain assessment in the document. For floodplain actions for which DOE does not have to prepare such a document, the Department is to issue a separate document as the floodplain assessment. After the conclusion of public comment, DOE is to reevaluate the practicability of alternatives and of mitigation measures, considering all substantive comments.

If it finds that no practicable alternative to locating in the floodplain is available, DOE must design or modify its action to minimize potential harm to and within the floodplain. For actions in a floodplain, DOE must publish a statement of findings of three pages or less containing a brief description of the proposed action, a location map, an explanation indicating the reason for locating the action in the floodplain, a list of alternatives considered, a statement indicating whether the action conforms to applicable State or local floodplain protection standards, and a brief description of steps DOE will take to minimize potential harm to or within the floodplain. For floodplain actions that require the preparation of an EIS, the Final EIS can incorporate the statement of findings. Before implementing a proposed floodplain action, DOE must endeavor to allow at least 15 days of public review of the statement of findings.

Appendix L contains a floodplain/wetlands assessment that examines the effects of proposed repository construction and operation and potential construction of a rail line or intermodal transfer station. The assessment includes discussion of:

1. Floodplains near Yucca Mountain (Fortymile Wash, Busted Butte Wash, Drillhole Wash, and Midway Valley Wash); there are no delineated wetlands at Yucca Mountain.

2. What is known about floodplains and areas that might have wetlands (for example, springs and riparian areas) along potential rail corridors in Nevada and at intermodal transfer station locations associated with heavy-haul routes. If DOE selects rail as the mode of spent nuclear fuel and high-level radioactive waste transport in Nevada to Yucca Mountain, one of five rail corridors would be selected. If DOE selected heavy-haul as the mode of transport for spent nuclear fuel and high-level radioactive waste to Yucca Mountain, it would select one of five heavy-haul routes and one of three intermodal transfer stations, and would prepare a more detailed floodplain/wetlands assessment of the selected rail corridor or heavy-haul route.

11.2.3 HAZARDOUS MATERIALS PACKAGING AND TRANSPORTATION

Hazardous Materials Transportation Act (49 USC 1801)
The Hazardous Materials Transportation Act gives the U.S. Department of Transportation authority to regulate the transport of hazardous materials, including radioactive materials such as those that would be transported to the proposed Yucca Mountain Repository from 72 commercial and 5 DOE sites. Department of Transportation regulations (49 CFR Parts 171 through 180) would require the identification of hazardous materials during transportation to a repository at Yucca Mountain, set forth rules for the selection of routes that carriers must use when transporting such materials, and provide guidance to states in designating preferred routes.

Emergency Planning and Community Right-to-Know Act of 1986 (42 USC 1001 *et seq.*)
Under Subtitle A of the Emergency Planning and Community Right-to-Know Act (also known as "SARA Title III"), Federal facilities, including a repository at Yucca Mountain, must provide information on hazardous and toxic chemicals to state emergency response commissions, local emergency planning committees, and the Environmental Protection Agency. The goal of providing this information is to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. The required information includes inventories of specific chemicals used or stored and descriptions of releases that occur from sites. This law, implemented at 40 CFR Parts 302 through 372, requires agencies to provide material safety data sheet reports, emergency and hazardous chemical inventory reports, and toxic chemical release reports to appropriate local, state, and Federal agencies. DOE has been complying with the provisions of the Emergency Planning and Community Right-to-Know Act and with regulations for maintaining and using inventories of chemicals for site characterization activities. If the proposed repository received a license, DOE would continue to comply with such provisions, as applicable, in storing and using chemicals for project activities.

Nevada Revised Statutes: Hazardous Materials, Chapter 459
A Nevada Hazardous Materials Storage Permit could be required to store hazardous materials in quantities greater than those specified in the Uniform Fire Code. To receive such a permit, if sought, DOE would submit an application to the Nevada State Fire Marshal (Nevada Revised Statutes, Chapter 477) that describes its plans for the storage of hazardous materials in excess of specified quantities (see Table 11-1, item 16). If permit renewal was sought each year, DOE would have to submit an annual report to the State Fire Marshal that complied with the reporting requirements of the Federal Emergency Planning and Community-Right-to-Know Act, Sections 302, 311, and 312. Regardless of whether these provisions are applicable, DOE has obtained a permit from the State Fire Marshal for the storage of flammable materials during site characterization activities.

Nuclear Regulatory Commission Radioactive Materials Packaging and Transportation Regulations (10 CFR Parts 71 and 73)
Under 10 CFR Part 71, the Nuclear Regulatory Commission regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of radioactive material and the DOE Office of Civilian Radioactive Waste Management. In addition, under an agreement with the U.S. Department of Transportation, the Commission sets the standards for packages containing Type B quantities of radioactive materials, including high-level radioactive waste and spent nuclear fuel. Type B packages are designed and built to retain their radioactive contents in both normal and accident conditions.

The demonstration of compliance with these requirements applies a combination of simple calculational methods, computer modeling techniques, and physical testing to the design features of the package. An applicant presents the results of the analyses and tests to the Nuclear Regulatory Commission in a Safety

Analysis Report for Packaging, which the Commission, after review, approves by issuing a Certificate of Compliance. This certificate would be required for the use of a package (cask) to ship spent nuclear fuel or high-level radioactive waste to the repository.

The regulations at 10 CFR Part 73 govern safeguards and physical security during the transit of shipments of spent nuclear fuel. These regulations specify requirements for vehicles, carrier personnel, communications, notification of state governors, escorts, and route planning for such shipments.

Department of Transportation Hazardous Materials Packaging and Transportation Regulations 49 CFR Subchapter C – Hazardous Materials Regulations, Parts 171 Through 180)

The Department of Transportation regulates the shipments of hazardous materials, including spent nuclear fuel and high-level radioactive waste, in interstate and intrastate commerce by land, air, and navigable water. As outlined in a 1979 Memorandum of Understanding with the Nuclear Regulatory Commission (44 *FR* 38690, July 2, 1979), the Department of Transportation specifically regulates carriers of spent nuclear fuel and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. It also regulates the labeling, classification, and marking of transportation packages for radioactive materials.

Department of Transportation regulations include requirements for carriers, drivers, vehicles, routing, packaging, labeling, marking, placarding of vehicles, shipping papers, training, and emergency response. The requirements specify the maximum dose rate associated with radioactive material shipments and the maximum allowable levels of radioactive surface contamination on packages and vehicles.

The public highway routing regulations of the Department of Transportation are prescribed in 49 CFR Part 397. The objectives of the regulations are to reduce the impacts of transporting highway route-controlled quantities of radioactive materials to establish consistent and uniform requirements for route selection, and to identify the role of state and local governments in the routing. The requirements at 49 CFR 173.403(l) contain a complete definition of a highway route-controlled quantity of radioactive material. A highway route-controlled quantity of radioactive material (49 CFR 173.403) is a quantity in a single package (shipping cask) that exceeds the smallest of:

- 3,000 times the A_1 values of the radionuclides as specified in 10 CFR 173.435 for special form Class 7 (radioactive) material
- 3,000 times the A_2 values of the radionuclides as specified in 10 CFR 173.433 for normal form Class 7 (radioactive) material
- 27,000 curies

Shipping casks transported by legal-weight trucks typically would contain about 300,000 curies of radionuclides, and rail casks typically would contain larger quantities. These regulations attempt to reduce potential hazards by requiring the use of routes that avoid populous areas and minimize travel times. At present, the Department of Transportation does not regulate the routing of rail shipments of radioactive materials. Department of Transportation regulations also include requirements to protect the health and safety of transportation workers.

11.2.4 CONTROL OF POLLUTION

Pollution Prevention Act of 1990 (42 USC 13101 *et seq.*)

The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmentally safe recycling, treatment, and

disposal. DOE requires each of its sites to establish specific goals to reduce the generation of waste. If the Department built and operated a repository at the Yucca Mountain site, it would implement an appropriate pollution prevention plan. DOE has implemented a pollution prevention plan for site characterization activities. DOE would update this plan to include construction, operation and monitoring, and closure activities if the repository received a license.

Comprehensive Environmental Response, Compensation, and Liability Act, as amended (42 USC 9601 *et seq.*)
The Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act, authorizes the Environmental Protection Agency to require responsible site owners, operators, arrangers, and transporters to clean up releases of hazardous substances, including certain radioactive substances. Under this Act, the Environmental Protection Agency would have the authority to regulate hazardous substances, including certain radioactive materials, at the Yucca Mountain Repository in the event of a release or a "substantial threat of a release" of those materials from the repository. Releases greater than reportable quantities would be reported to the National Response Center.

Standards for Protection Against Radiation (10 CFR Part 20)
The purpose of 10 CFR Part 20 is to provide standards and procedures for protection against radiation. Provisions of 10 CFR Part 20 address radiation protection programs, occupational dose limits, public dose limits, survey and monitoring procedures, exposure control in restricted areas, respiratory protection and controls, precautionary procedures, and related topics.

Resource Conservation and Recovery Act, as amended (42 USC 6901 *et seq.*)
The treatment, storage, and disposal of hazardous and nonhazardous waste is regulated in accordance with the provisions of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984, and applicable state laws.

Environmental Protection Agency regulations implementing the hazardous waste portions of the Resource Conservation and Recovery Act define hazardous wastes and specify requirements for their transportation, handling, treatment, storage, and disposal (40 CFR Parts 260 through 272). In addition, under current Civilian Radioactive Waste system requirements, DOE could not accept hazardous waste for disposal at Yucca Mountain. Before shipping to Yucca Mountain, DOE would treat materials that contained hazardous components to eliminate the hazardous waste characteristics. Before shipping materials containing hazardous components listed under Subpart D of Part 261 or applicable state requirements, DOE would process any necessary delisting petitions with the appropriate regulatory authorities. If the activities at Yucca Mountain generated hazardous or mixed waste, the Department would not treat or dispose of such waste on the site, and would not store such waste on the site for more than 90 days. DOE does not expect to need a Resource Conservation and Recovery Act permit for its activities at the proposed repository.

Noise Control Act of 1972, as amended (42 USC 4901 *et seq.*)
Section 4 of the Noise Control Act directs Federal agencies to carry out programs in their jurisdictions "to the fullest extent within their authority" and in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare. This law provides requirements related to noise that would be generated by construction, operation, or closure activities associated with the Proposed Action at Yucca Mountain.

Nevada Revised Statutes: Sanitation, Chapter 444

These statutes and regulations in the Nevada Administrative Code establish the standards, permits, and requirements for septic tanks and other sewage disposal systems for single-family dwellings, communities, and commercial buildings. The construction and operation of a sanitary sewage collection system at Yucca Mountain could require the State of Nevada to approve DOE designs and to issue a permit. In connection with site characterization activities, DOE operates a septic system that the State has permitted under these provisions.

These statutes and regulations also set forth the definitions, methods of disposal, special requirements for solid waste collection and transportation standards, and classification of landfills. Onsite disposal of solid waste from a repository at Yucca Mountain could require that DOE obtain an appropriate permit for these activities.

In compliance with the Resource Conservation and Recovery Act, the Environmental Protection Agency has authorized the State of Nevada to regulate the management and disposal of solid, hazardous, and mixed wastes in the State. The Nevada Division of Environmental Protection or an equivalent solid waste management authority would regulate the onsite disposal of nonhazardous solid wastes generated by activities associated with the proposed repository. DOE would manage such waste in accordance with applicable laws and regulations.

Nevada Administrative Code Chapter 444 contains regulations that provide for fees, variances, and permits, and has adopted Environmental Protection Agency regulations (40 CFR Parts 2, 124, and 260 through 270) as part of the code. The regulations could affect any hazardous or mixed waste generated, treated, or stored onsite by activities associated with a proposed repository at Yucca Mountain. DOE would ship any generated hazardous or mixed wastes off the site within 90 days for treatment, storage, and disposal.

Executive Order 12088, *Federal Compliance with Pollution Control Standards*

Executive Order 12088, as amended by Executive Order 12580, *Federal Compliance with Pollution Control Standards*, generally directs Federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act, the Noise Control Act, the Clean Water Act, the Safe Drinking Water Act, the Toxic Substances Control Act, and the Resource Conservation and Recovery Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

Executive Order 12856, *Right to Know Laws and Pollution Prevention Requirements*

This Order directs Federal agencies to reduce and report toxic chemicals entering any waste stream; improve emergency planning, response, and accident notification; and encourage the use of clean technologies and testing of innovative prevention technologies. In addition, the Order states that Federal agencies are persons for purposes of the Emergency Planning and Community Right-to-Know Act (SARA Title III), which requires agencies to meet the requirements of the Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

11.2.5 CULTURAL RESOURCES

National Historic Preservation Act, as amended (16 USC 470 *et seq.*)

The National Historic Preservation Act provides for the placement of sites with significant national historic value on the *National Register of Historic Places*. It requires no permits or certifications. DOE would evaluate activities associated with a repository at Yucca Mountain to determine if they would

affect historic resources. If required after this evaluation, the Department would consult with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer. Such consultations generally result in the development of an agreement that includes stipulations to be followed to minimize or mitigate potential adverse impacts to a historic resource (see Table 11-1, item 9).

DOE has entered into a programmatic agreement with the Advisory Council on Historic Preservation for implementation of the National Historic Preservation Act for site characterization activities. This agreement requires DOE to consult and interact with Native Americans during site characterization. In compliance with the agreement provisions, Native American representatives from the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have reviewed Yucca Mountain activities on the site twice each year. These reviews have been followed by discussions between Native American representatives and DOE personnel, submittal of comments by the Native American representatives, and responses to the comments by DOE. If the proposed site was authorized, the implementing agreement would be modified as appropriate and additional consultations would occur under Section 106 of the National Historic Preservation Act (16 USC 106).

Archaeological Resources Protection Act, as amended (16 USC 470aa *et seq.*)

The Archaeological Resources Protection Act requires a permit for excavation or removal of archaeological resources from publicly held or Native American lands (see Table 11-1, item 11). Excavations must further archaeological knowledge in the public interest, and the resources removed are to remain the property of the United States. If a resource is found on land owned by a Native American tribe, the tribe must give its consent before a permit is issued, and the permit must contain terms or conditions requested by the tribe. Requirements of the Archaeological Resources Protection Act would apply to any Yucca Mountain Project excavation activities that resulted in identification of archaeological resources.

American Indian Religious Freedom Act of 1978 (42 USC 1996)

The American Indian Religious Freedom Act reaffirms Native American religious freedom under the First Amendment and establishes policy to protect and preserve the inherent and constitutional right of Native Americans to believe, express, and exercise their traditional religions. This law ensures the protection of sacred locations and access of Native Americans to those sacred locations and traditional resources that are integral to the practice of their religions. Further, it establishes requirements that would apply to Native American sacred locations, traditional resources, or traditional religious practices potentially affected by the construction and operation of a repository at Yucca Mountain.

Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001)

The Native American Graves Protection and Repatriation Act directs the Secretary of the Interior to guide the repatriation of Federal archaeological collections and collections that are culturally affiliated with Native American tribes and held by museums that receive Federal funding. Major actions to be taken under this law include (1) the establishment of a review committee with monitoring and policymaking responsibilities, (2) the development of regulations for repatriation, including procedures for identifying lineal descent or cultural affiliation needed for claims, (3) the oversight of museum programs designed to meet the inventory requirements and deadlines of this law, and (4) the development of procedures to handle unexpected discoveries of graves or grave goods during activities on Federal or tribal land. The provisions of the Act would be invoked if any excavations associated with a repository at Yucca Mountain led to unexpected discoveries of Native American graves or grave artifacts. DOE and the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have entered an agreement to address the potential applicability of the Native American Graves Protection and Repatriation Act to artifacts collected during site characterization activities at Yucca Mountain.

Antiquities Act (16 USC 431 *et seq.*)

The Antiquities Act protects historic and prehistoric ruins, monuments, and objects of antiquity (including paleontological resources) on lands owned or controlled by the Federal Government. If historic or prehistoric ruins or objects were found during the construction or operation of facilities associated with a repository at Yucca Mountain, DOE would have to determine if adverse effects to these ruins or objects would occur. If adverse effects would occur, the Secretary of the Interior would have to grant permission to proceed with the activity (36 CFR Part 296 and 43 CFR Parts 3 and 7) (see Table 11-1, item 10).

Executive Order 11593, *National Historic Preservation*

This Order directs Federal agencies, including DOE, to locate, inventory, and nominate properties under their jurisdiction or control to the *National Register of Historic Places*. This process requires DOE to provide the Advisory Council on Historic Preservation the opportunity to comment on the possible impacts of proposed activities.

Executive Order 13007, *Indian Sacred Sites*

This Order directs Federal agencies, to the extent permitted by law and not inconsistent with agency missions, to avoid adverse effects to sacred sites and to provide access to those sites to Native Americans for religious practices. The Order directs agencies to plan projects to provide protection of and access to sacred sites to the extent compatible with the project.

Executive Order 13094, *Consultation and Coordination with Indian Trial Governments*

This Order directs Federal agencies to establish regular and meaningful consultation and collaboration with tribal governments in the development of regulatory practices on Federal matters that significantly or uniquely affect their communities; reduce the imposition of unfunded mandates on tribal governments; and streamline the application process for and increase the availability of waivers to tribal governments.

11.2.6 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Environmental Justice*

This Order directs Federal agencies, to the extent practicable, to make the achievement of environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations in the United States and its territories and possessions. The order provides that the Federal agency responsibilities it establishes are to apply equally to Native American programs.

11.2.7 ECOLOGY AND HABITAT

Endangered Species Act, as amended (16 USC 1531 *et seq.*)

The Endangered Species Act provides a program for the conservation of threatened and endangered species and the ecosystems on which those species rely. If a proposed action could affect threatened or endangered species or their habitat, the Federal agency must assess the potential impacts and develop measures to minimize those impacts. The agency then must consult with the Fish and Wildlife Service (part of the U.S. Department of the Interior) and the National Marine Fisheries Service (part of the Department of Commerce), as required under Section 7 of the Act. The outcome of this consultation would be a biological opinion by the Fish and Wildlife Service or the National Marine Fisheries Service that stated whether the proposed action would jeopardize the continued existence of the species under consideration. If there is a non-jeopardy opinion, but if some individuals might be killed incidentally as a result of the proposed action, the Services can determine that such losses are not prohibited as long as

measures outlined by the Services are followed. Regulations implementing the Endangered Species Act are codified at 50 CFR Parts 15 and 402.

There are no known endangered species on the Yucca Mountain site. The desert tortoise is the only threatened species found on the site. The Fish and Wildlife Service has issued a biological opinion stating that site characterization activities at Yucca Mountain would not jeopardize the continued existence of the desert tortoise (Buchanan 1997, page 16).

DOE will prepare a biological assessment on the effects of the proposed repository on threatened or endangered species before making a determination whether to recommend approval of the Yucca Mountain Site. In addition, DOE will fulfill the requirements of the Endangered Species Act, as appropriate, with regard to transportation impacts before making the recommendation determination.

Fish and Wildlife Coordination Act, as amended (16 USC 661, 48 Stat. 401)

The Fish and Wildlife Coordination Act promotes more effectual planning and cooperation between Federal, state, public, and private agencies for the conservation and rehabilitation of the Nation's fish and wildlife and authorizes the Department of the Interior to provide assistance.

Migratory Bird Treaty Act, as amended (16 USC 703 *et seq.*)

The purpose of the Migratory Bird Treaty Act is to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the take and harvest of migratory birds. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed would comply with the requirements of the Migratory Bird Treaty Act. Studies indicate that no requirements of this Act are applicable to the Yucca Mountain Project.

Bald and Golden Eagle Protection Act, as amended (16 USC 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Section 668, 668c). The Department of the Interior regulates activities that might adversely affect bald and golden eagles. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed in this EIS would comply with the Bald and Golden Eagle Protection Act. DOE has established a program to ensure compliance with this law during site characterization activities.

National Wildlife Refuge System Administration Act of 1966 (42 USC 668dd)

The National Wildlife Refuge System Administration Act provides guidelines for the administration and management of lands in the system, including "wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas." If use of lands for transportation corridors and facilities such as a rail line or intermodal transfer station associated with a repository at Yucca Mountain could affect lands in the system, DOE would consult with the Fish and Wildlife Service. Regulations implementing the Act are codified at 50 CFR Parts 25 and 27 through 29. The Fish and Wildlife Service will review this EIS to determine if the Proposed Action would comply with the Act. It is DOE policy to place transportation corridors and facilities to avoid existing wildlife refuges.

Nevada Revised Statutes: Protection and Preservation of Timbered Lands, Trees, and Flora, Chapter 527

These provisions broadly protect the indigenous flora of the State of Nevada. If the State determines that a species or subspecies of native flora is threatened with extinction, that species or subspecies is to be placed on the State list of fully protected species. In general, no member of the species or subspecies may be taken or destroyed unless an authorized State official issues a special permit. Activities

associated with a repository at Yucca Mountain arguably could affect such species and could require special permits.

Nevada Revised Statutes: Hunting, Fishing, and Trapping; Miscellaneous Protective Measures, Chapter 503; Nevada Administrative Code, Chapter 503: Sections 010-104, General Provisions

These provisions specify procedures for the classification and protection of wildlife. If the State determines that an animal species is threatened with extinction, the species is to be placed on the State list of fully protected species. In general, no member of the species may be taken or destroyed unless the Nevada Division of Wildlife issues a special permit. Activities associated with a repository at Yucca Mountain arguably could affect such species and could require special permits. Regardless of whether these provisions are applicable, DOE has obtained a permit for site characterization activities from the State of Nevada.

Executive Order 11990, *Protection of Wetlands*

This order directs Federal agencies to avoid new construction in wetlands unless there is no practicable alternative and unless the proposed action includes all practicable measures to minimize harm to wetlands that might result from such use. DOE requirements for compliance with wetlands activity review procedures are codified at 10 CFR Part 1022.

Executive Order 13112, *Invasive Species*

This order directs Federal agencies to act to prevent the introduction of or to monitor and control invasive (non-native) species, to provide for restoration of native species, to conduct research, to promote educational activities, and to exercise care in taking actions that could promote the introduction or spread of invasive species. If a repository were constructed at Yucca Mountain, DOE would comply with provisions of this Executive Order as part of construction, operation and monitoring, and closure activities.

11.2.8 USE OF LAND AND WATER BODIES

Coastal Zone Management Act (16 USC 1451 *et seq.*)

The purpose of the Coastal Zone Management Act is to preserve, protect, develop, restore, and enhance the resources of the Nation's coastal zone. Resources include wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat. This law provides for (1) management to minimize the loss of life and property caused by improper development and by the destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands, and (2) improvement, safeguarding, and restoration of the quality of coastal waters, and for protection of existing uses of those waters. The Coastal Zone Management Act requires priority consideration to coastal-dependent uses and orderly processes for siting major facilities related to national defense, energy, fisheries development, recreation, ports and transportation, and the location of new commercial and industrial developments in or adjacent to areas where such development already exists.

The operation of a repository at Yucca Mountain could require the use of barges for transportation of spent nuclear fuel along portions of routes from some storage facilities. In addition, rail corridors, roads, and bridges from some storage facilities could require repair or enhancement before they could support shipment of spent nuclear fuel. DOE would ensure that its activities are consistent with state-specific coastal zone management plans promulgated in accordance with this Act, if applicable. The regulations promulgated under the Act are codified at 15 CFR Part 930.

Rivers and Harbors Act (33 USC 401 *et seq.*)

The transportation of spent nuclear fuel and high-level radioactive waste could require the construction or modification of road or rail bridges that span navigable waters. The Rivers and Harbors Act prevents the alteration or modification of the course, location, condition, or capacity of any channel of any navigable water of the United States without a permit from the U.S. Army Corps of Engineers. If DOE assumed responsibility for such construction or modifications, it would need to obtain a permit from the U.S. Army Corps of Engineers. Regulations implementing this Act are codified at 33 CFR Part 323.

National Forest Organic Administrative Act (16 USC 521)

The National Forest Organic Administrative Act establishes the functions and responsibilities of the Forest Service, an agency of the U.S. Department of Agriculture. The Forest Service would be requested to approve the construction of rail lines and roads in Nevada that would be associated with the operation of a repository at Yucca Mountain and that could cross land administered by the Service (16 USC 1600, 1611-14).

National Forest Management Act of 1976

The National Forest Management Act establishes decision planning and management practices for forests. This law could affect any proposed construction of rail lines or roads associated with the construction or operation of a repository at Yucca Mountain that could cross National Forest lands.

Materials Act of 1947 (30 USC 601-603)

The Materials Act authorizes land management agencies, such as the Bureau of Land Management and the Forest Service, to make common varieties of sand, stone, and gravel from public lands available to Federal and state agencies under a Free Use Permit (see Table 11-1, item 12). Regulations implementing the Materials Act are codified at 43 CFR Part 3600. DOE has received three free use permits from the Bureau of Land Management to obtain gravel for site characterization activities in a manner compliant with the Materials Act.

Taylor Grazing Act (43 USC 315-316)

The Taylor Grazing Act establishes the processes by which the Bureau of Land Management grants and administers grazing rights. If a decision is made to construct and operate a repository, a new rail line, or a new road on a Bureau of Land Management grazing allotment, DOE would have to acquire a right-of-way grant across the allotment or a withdrawal of the allotment. Regulations implementing this Act are codified at 43 CFR Part 4100.

Farmland Protection Policy Act (7 USC 4201 *et seq.*)

The Farmland Protection Policy Act seeks to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses. Compliance with this law requires concurrence from the Natural Resources Conservation Service of the U.S. Department of Agriculture that proposed activities would not affect farmlands. DOE has completed a consultation with the Natural Resources Conservation Service that determined that a repository at Yucca Mountain would not affect prime or unique farmlands. This EIS assesses the potential construction of a rail line, new roads, or an intermodal transfer station in Nevada to determine if that construction could affect such lands. Regulations implementing the Farmland Protection Policy Act are codified at 7 CFR Part 658.

11.3 Department of Energy Orders

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the

issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Table 11-2 lists DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program.

Table 11-2. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 1 of 2).

Order	Subject	Description
151.1	Comprehensive Emergency Management System	Establishes requirements for emergency planning, preparedness, response, recovery, and readiness assurance activities and describes the approach for effectively integrating these activities under a comprehensive, all-emergency concept.
231.1	Environment, Safety and Health Reporting	Establishes the requirements and procedures for reporting information with environmental protection, safety, or health protection significance for DOE operations.
232.1	Occurrence Reporting and Processing of Operations Information	Establishes the requirements for reporting and processing occurrences related to safety, health, security, property, operations, and the environment, up to and including emergencies.
250.1	Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives	Establishes the relationship between DOE directives and Nuclear Regulatory Commission regulations for the Yucca Mountain Project.
420.1A	Facility Safety	Establishes facility safety requirements related to nuclear safety design, criticality safety, fire protection, and natural phenomena hazards mitigation.
425.1	Facility Startup and Restart	Establishes procedures to be followed when a facility is taken from a nonoperational to an operational state.
430.1	Life Cycle Asset Management	Establishes procedures to be followed in all phases of the management of DOE facilities.
440.1A	Worker Protection Management for DOE Federal and Contractor Employees	Establishes a comprehensive worker protection program that ensures that DOE and its contractor employees have an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE, Federal, and contractor workers with a safe and healthful workplace.
451.1A	National Environmental Policy Act Compliance Program	Establishes DOE internal requirements and responsibilities for implementing the National Environmental Policy Act of 1969, as amended, the Council on Environmental Quality regulations implementing the procedural provisions of the Act (40 CFR Part 1500 *et seq.*), and the DOE procedures that implement it (10 CFR Part 1021).
460.1A	Packaging and Transportation Safety	Establishes requirements and assigns responsibilities for the safe transport of hazardous materials, hazardous substances, hazardous wastes, and radioactive materials.
1300.2A	Department of Energy Technical Standards Program	Establishes policy, assigns responsibility, and provides requirements for development and application of technical standards in DOE facilities, programs, and projects; provides for participation in non-Government standards bodies and for establishment of a DOE Technical Standards Program; and assigns responsibility for the management of the program.
1360.2B	Unclassified Computer Security Program	Establishes requirements, policies, responsibilities, and procedures for developing, implementing, and sustaining a DOE unclassified computer security program.

Table 11-2. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 2 of 2).

Order	Subject	Description
3790.1B	Federal Employee Occupational Safety and Health Program	Establishes requirements and procedures to ensure that occupational safety and health standards prescribed pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, and the DOE Organization Act of 1977 provide occupational safety and health protection for DOE contractor employees in Government-owned contractor-operated facilities.
5400.1	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations to ensure compliance with applicable Federal, state, and local environmental protection laws and regulations and with internal DOE policies.
5400.5	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operation of DOE and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.
5480.19	Conduct of Operations Requirements for DOE Facilities	Provides requirements and guidelines for DOE elements to use in developing directives, plans, and procedures related to the conduct of operations at DOE facilities.
5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements	Establishes the requirements and procedures for the investigation of occurrences having environmental protection, safety, or health protection significance, and for efficient environmental monitoring of DOE operations.
5610.14	Transportation Safeguards System Program Operations	Establishes DOE policies for and implementation of the management and operation of the Transportation Safeguards System program.
5632.1C	Protection and Control of Safeguards and Security Interests	Establishes policy, responsibilities, and authorities for the protection and control of safeguards and security interests (for example, special nuclear material, vital equipment, classified matter, property, facilities, and unclassified irradiated reactor fuel in transit).
5633.3B	Control and Accountability of Nuclear Materials	Prescribes the minimum DOE requirements and procedures for control and accountability of nuclear materials at DOE-owned and -leased facilities and DOE-owned nuclear materials at facilities that are exempt from licensing by the Nuclear Regulatory Commission. Would apply to materials destined for a repository before the materials reached the repository.
5820.2A	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.

The Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository. Some DOE Orders overlap or duplicate Nuclear Regulatory Commission repository licensing regulations in whole or in part. Recognizing this, the Department issued DOE HQ Order 250.1, *Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives.* This Order exempts geologic repository design, construction, operation, and decommissioning from compliance with the provisions of DOE Orders that overlap or duplicate Commission requirements related to radiation protection, nuclear safety (including quality assurance), and safeguard and security of nuclear material. The exemption would apply only to portions of a repository project for which DOE sought a Nuclear Regulatory Commission license. DOE Orders would continue to establish requirements for other activities associated with a repository that fall outside the scope of this exemption, for example in the area of computer security (Order 1360.28).

Through DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees,* the Department has prescribed the Occupational Safety and Health Act standards that contractors are to meet in their work at government-owned, contractor-operated facilities.

A monitored geologic repository at Yucca Mountain would be a nonreactor nuclear facility. DOE Orders 5480.21, *Unreviewed Safety Questions,* 5480.22, *Technical Safety Requirements,* and 5480.23, *Nuclear Safety Analysis Reports,* ordinarily apply to nonreactor nuclear facilities. Because DOE Order 250.1 gives precedence to Nuclear Regulatory Commission rules, DOE Orders 5480.21, 5480.22, and 5480.23, for example, probably would not apply to the repository.

11.4 Potentially Applicable Federal Regulations

Sections 11.2.1 through 11.2.3 identify major laws, regulations, and DOE Orders potentially applicable to the construction, operation and monitoring, and closure of a monitored geologic repository. Table 11-3 lists other potentially applicable regulations and orders.

Table 11-3. Potentially applicable Federal regulations, orders, standards, and memoranda (page 1 of 3).

Document Number	Title[a]
Code of Federal Regulations	
10 CFR 2	Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders
10 CFR 19	Notices, Instructions and Reports to Workers: Inspection and Investigations
10 CFR 40	Domestic Licensing of Source Material
10 CFR 51	Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions
10 CFR 60	Licensing Requirements for Geologic Repository
10 CFR 61	Licensing Requirements for Land Disposal of Radioactive Waste
10 CFR 72	Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Waste
10 CFR 73	Physical Protection of Plants and Materials
10 CFR 75	Safeguards on Nuclear Material-Implementation of US/IAEA Agreement
10 CFR 100	Reactor Site Criteria
10 CFR 707	Workplace Substance Abuse Programs at DOE Sites
10 CFR 830	Nuclear Safety Management
10 CFR 835	Occupational Radiation Protection
10 CFR 960	General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories
10 CFR 1022	Compliance with Floodplain/Wetlands Environmental Review Requirements
29 CFR 1926	Safety and Health Regulations for Construction
29 CFR 1960	Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters
30 CFR 57	Safety and Health Standards, Underground Metal and Nonmetal Mines
33 CFR 323	Permits for Discharges of Dredged or Fill Material into Waters of the United States
33 CFR Chapter I	Coast Guard Department of Transportation (Parts 1-199)
36 CFR 296	Permits to Proceed (Objects of Antiquity)
36 CFR 800	Protection of Historic and Cultural Properties
40 CFR 50	National Primary and Secondary Ambient Air Quality Standards
40 CFR 60	Standards of Performance for New Stationary Sources
40 CFR 61	National Emission Standards for Hazardous Air Pollutants
40 CFR 63	National Emission Standards for Hazardous Air Pollutants for Source Categories
40 CFR 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System
40 CFR 125	Criteria and Standards for the National Pollutant Discharge Elimination System
40 CFR 133	Secondary Treatment Regulation
40 CFR 136	Guidelines Establishing Test Procedures for the Analysis of Pollutants

Table 11-3. Potentially applicable Federal regulations, orders, standards, and memoranda (page 2 of 3).

Document Number	Title[a]
Code of Federal Regulations (continued)	
40 CFR 141	National Primary Drinking Water Regulations
40 CFR 142	National Primary Drinking Water Regulations Implementation
40 CFR 143	National Secondary Drinking Water Regulations
40 CFR 246	Source Separation for Materials Recovery Guidelines
40 CFR 257	Criteria for Classification of Solid Waste Disposal Facilities and Practices
40 CFR 260	Hazardous Waste Management System: General
40 CFR 261	Identification and Listing of Hazardous Waste
40 CFR 262	Standards Applicable to Generators of Hazardous Waste
40 CFR 263	Standards Applicable to Transporters of Hazardous Waste
40 CFR 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR 265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR 268	Land Disposal Restrictions
40 CFR 280	Technical Standards and Corrective Action Requirements for Owners and Operàtors of Underground Storage Tanks
40 CFR 503	Standards for the Use or Disposal of Sewage Sludge
40 CFR 747	Metalworking Fluids
40 CFR 761	Polychlorinated Biphenyls Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions
40 CFR 1500	Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act
41 CFR 101	Federal Property Management Regulations
43 CFR 3 and 7	Preservation of Antiquities, Protection of Archaeological Resources
43 CFR 2300	Land Withdrawal
43 CFR 3600	Free Use Permit
43 CFR 4100	Right-of-Way Reservation
49 CFR 171	General Information, Regulations and Definitions
49 CFR 172	Hazardous Materials Table, Special Provisions, Hazardous Materials Communications Requirements and Emergency Response Information Requirements
49 CFR 173	Shippers – General Requirements for Shipments and Packagings
49 CFR 174	Carriage by Rail
49 CFR 176	Carriage by Vessel
49 CFR 177	Carriage by Public Highway
49 CFR 178	Shipping Container Specifications
49 CFR 180	Continuing Qualification and Maintenance of Packagings
49 CFR 392	Driving of Motor Vehicles
49 CFR 393	Parts and Accessories Necessary for Safe Operation
50 CFR 17	Endangered and Threatened Wildlife and Plants
50 CFR 400	Endangered Species Act
50 CFR 402	Interagency Cooperation – Endangered Species Act of 1973, as Amended
Executive Orders	
Executive Order 11514	National Environmental Policy Act, Protection and Enhancement of Environmental Quality
Executive Order 11593	National Historic Preservation
Executive Order 11988	Floodplain Management
Executive Order 11990	Protection of Wetlands
Executive Order 12856	Right to Know Laws and Pollution Prevention Requirements
Executive Order 12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
Executive Order 13007	Indian Sacred Sites
Executive Order 13084	Consultation and Coordination with Indian Tribal Governments
Executive Order13112	Invasive Species

Table 11-3. Potentially applicable Federal regulations, orders, standards, and memoranda (page 3 of 3).

Document Number	Title[a]
Other documents, orders, and directives	
AAR Rule 91	1993 Field Manual of Association of American Railroads Interchange Rules (AAR Interchange Rule 91, Weight Limitations)
BLM Manual, Sec. 9113	Bureau of Land Management Manual, Road Standards
DOE Order 430.1	Life Cycle Asset Management
DOE Order 3790.1	Federal Employees Occupational Safety and Health Program
DOE Order 5480.4	Environmental Protection, Safety, and Health Protection Standards
DOE Order 5632.1	Protection Program Operation
DOE/EA-0179	Environmental Assessment Waste Form Selection for Savannah River HLW
DOE/EH-0256T	DOE Radiological Control Manual
DOE/RW-0184	Characteristics of Potential Repository Wastes, Volumes 1-4
DOE/RW-0194P	Records Management Policies and Requirements
DOE/RW-0328P	Acceptance Priority Ranking
DOE/RW-0333P	OCRWM Quality Assurance Requirements and Description
DOE/RW-0457	1995 Acceptance Priority Ranking and Annual Capacity Report
DOE-STD-1020	Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
DOE-STD-1021	Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems and Components
DOE-STD-1022	Natural Phenomena Hazards Site Characterization Criteria
DOE-STD-1023	Natural Phenomena Hazards Assessment Criteria (Draft)
DOE-STD-1024	Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites
DOE-STD-1062	Ergonomic and Human Factors Design Criteria[b]
Fed-STD-795	Uniform Federal Accessibility Standards
GSA-FSS-W-A-450/1-17	General Service Administration Interim Federal Specification
MOA DP/RW	Policy for Shipping Defense High-Level Waste (DHLW) to a Civilian Radioactive Waste Repository
MOA RW/NS	Nuclear Safety Requirement
MOU DOE/DOL	Mining Safety
NRC RG 1.13	Spent Fuel Storage Facility Design Basis
NRC RG 1.76	Design Basis Tornado for Nuclear Power Plants
NRC RG 8.8	Information Relevant to Ensuring That Occupational Radiation Exposure at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable
NRC RG 8.10	Operating Philosophy for Maintaining Occupational Radiation Exposure As Low As Is Reasonably Achievable
NUREG 0700	Guidelines for Control Room Design Reviews
NUREG 0856	Final Technical Position on Documentation of Computer Codes for High-Level Waste Management
Presidential Memo (04/30/85)	Dispose of Defense Waste in a Commercial Repository

a. IAEA = International Atomic Energy Agency; EPA = Environmental Protection Agency; HLW = high-level radioactive waste; OCRWM = Office of Civilian Radioactive Waste Management.

b. This standard is complete, but has not been formally published at this time. However, it is included here as a source because it consists of a compilation of requirements from accepted sources. Those sources include standards from the Code of Federal Regulations, Nuclear Regulatory Commission regulations, and military, American National Standards Institute, National Aeronautics and Space Administration, and Electric Power Research Institute standards, as well as recognized design handbooks and guides that govern standard engineering practice.

12

References

12. REFERENCES

The following is a list of the references cited in this EIS. A DOE tracking and retrieving document identification number follows each reference citation. The purpose of these numbers is to assist the reader in locating a specific reference. Some reference citations have more than one tracking number, designating multiple volumes or a series of documents that relate to that particular reference.

AAR 1996	AAR (Association of American Railroads), 1996, *Railroad Facts, 1996 Edition,* Policy, Legislation and Economics Department, Washington, D.C. [243890]
ACGIH 1999	ACGIH (American Conference of Governmental Industrial Hygienists), 1999, *TLVs® and BEIs®, Threshold Limit Values for Chemical Substances and Physical Agents, Biological Exposure Indices,* Cincinnati, Ohio. [243476]
ACS 1998	ACS (American Cancer Society), 1998, *Cancer Facts & Figures – 1998,* Surveillance Research, Washington D.C. [242284]
AEC 1998	AEC (American Ecology Corporation), 1998, "1998 News Releases: Nevada Acceptance Makes American Ecology First U.S. Firm to Build, Operate, Successfully Close Radioactive Waste Facility," news release, January 6, Boise, Idaho. [243770]
AIWS 1998	AIWS (American Indian Writers Subgroup), 1998, *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement,* American Indian Resource Document, Consolidated Group of Tribes and Organizations, Las Vegas, Nevada. [MOL.19980420.0041]
American Trucking v. EPA 1999	United States Court of Appeals for the District of Columbia Circuit American Trucking Associations v. U.S. Environmental Protection Agency, 1999, No. 97-1440, May 14, District of Columbia Circuit, United States Circuit Court, Washington, D.C. [244121]
Andrews, Dale, and McNeish 1994	Andrews, R. W., T. F. Dale, and J. A. McNeish, 1994, *Total System Performance Assessment - 1993: An Evaluation of the Potential Yucca Mountain Repository,* B00000000-01717-2200-00099, Revision 01, Intera, Inc., Las Vegas, Nevada. [NNA.19940406.0158]
ANS 1992	ANS (American Nuclear Society), 1992, *Determining Design Basis Flooding at Power Reactor Sites: an American National Standard,* ANSI/ANS-2.8-1992, Working Group ANS-2.8, LaGrange Park, Illinois. [236034]
Ardila-Coulson 1989	Ardila-Coulson, M. V., 1989, *The Statewide Radioactive Materials Transportation Plan, Phase II,* College of Engineering, University of Nevada-Reno, Reno, Nevada. [222209]
ASTM 1994	ASTM (American Society for Testing and Materials), 1994, "Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod," B574-94, Conshohocken, Pennsylvania. [243913]

Barnard et al. 1992	Barnard, R. W., M. L. Wilson, H. A. Dockery, J. H. Gauthier, P. G. Kaplan, R. R. Eaton, F. W. Bingham, and T. H. Robey, 1992, *TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain,* SAND91-2795, Sandia National Laboratories, Albuquerque, New Mexico. [NNA.19920630.0033]
Barrett 1998	Barrett, L., 1998, "Program Briefing for the U.S. Chamber of Commerce Energy and Natural Resources Committee, November 9, 1998," Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Washington, D.C. [MOL.19990526.0026]
Bauer et al. 1996	Bauer, D. J., B. J. Foster, J. D. Joyner, and R. A. Swanson, 1996, *Water Resources Data for Nevada, Water Year 1995,* USGS-WDR NV-95-1, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [234695]
BEA 1992	BEA (Bureau of Economic Analysis), 1992, *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II), 2nd Edition,* REA 92-01, pages 24, 36, 38, 41, and 45, Economics and Statistics Administration, U.S. Department of Commerce, Washington, D.C. [242623]
Bechtel 1997	Bechtel Nevada, 1997, *Ecological Monitoring and Compliance Program Fiscal Year 1997 Report,* Ecological Services, Las Vegas, Nevada. [243786]
Bechtel 1998	Bechtel Nevada, 1998, *Nevada Test Site Annual Site Environmental Report for Calendar Year - 1997,* DOE/NV/11718--231, S.C. Black and Y. E. Townsend, editors, Las Vegas, Nevada. [242871]
Benson and McKinley 1985	Benson, L. V., and P. W. McKinley, 1985, *Chemical Composition of Ground Water in the Yucca Mountain Area, Nevada, 1971-84,* OFR-85-484, U.S. Geological Survey, U.S. Department of the Interior, in cooperation with the Nevada Operations Office, U.S. Department of Energy, Denver, Colorado. [203181]
Bland 1999	Bland, J., 1999, "Maps Showing Minority and Low-Income Census Block Groups in Nevada and Greater Las Vegas," memorandum with attachments (YMP-98-050_1.2, YMP-98-050_2.2, YMP-98-050_4.3, YMP-98-050_5.2) to File, February 17, Regional Studies Department, U.S. Department of Energy, Las Vegas, Nevada. [MOL.19990223.0199]
Blanton 1992	Blanton, J. O., III, 1992, *Nevada Test Site Flood Inundation Study: Part of a Geological Survey Flood Potential and Debris Hazard Study, Yucca Mountain Site for the U.S. Department of Energy (Office of Civilian Radioactive Waste Management),* Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado. [230563]
BLM 1979	BLM (Bureau of Land Management), 1979, *Final Environmental Statement Proposed Domestic Livestock Grazing Management Program for the Caliente Area,* Las Vegas District Office, U.S. Department of the Interior, Las Vegas, Nevada. [231827]

BLM 1983	BLM (Bureau of Land Management), 1983, *Draft Management Plan and Environmental Impact Statement for the Shoshone-Eureka Resource Area, Nevada,* INT DEIS 83-40, Battle Mountain District Office, U.S. Department of the Interior, Battle Mountain, Nevada. [241518]
BLM 1986	BLM (Bureau of Land Management), 1986, *Visual Resource Inventory,* BLM Manual Handbook 8410-1, U.S. Department of the Interior, Washington, D.C. [241833]
BLM 1988	BLM (Bureau of Land Management), 1988, *U.S. Department of the Interior Bureau of Land Management Right of Way Reservation, N-47748,* U.S. Department of the Interior, Las Vegas, Nevada. [MOL.19980513.0554]
BLM 1992	BLM (Bureau of Land Management), 1992, *Draft Stateline Resource Management Plan and Environmental Impact Statement,* U.S. Department of the Interior, Stateline Resource Area Office, Las Vegas, Nevada. [206004]
BLM 1994a	BLM (Bureau of Land Management), 1994a, *United States Department of the Interior Bureau of Land Management State Office Right-of-Way Reservation,* Renewal-Reservation N-48602, Effective July 1, 1994, Expiration January 6, 2001, Las Vegas District Office, U.S. Department of the Interior, Las Vegas, Nevada. [MOL.19981123.0235]
BLM 1994b	BLM (Bureau of Land Management), 1994b, *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement,* Tonopah Resource Area, Battle Mountain District, U.S. Department of the Interior, Tonopah, Nevada. [241484]
BLM 1996	BLM (Bureau of Land Management), 1996, *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement,* Volume I, U.S. Department of the Interior, Battle Mountain District Office, in cooperation with the Nevada Division of Water Resources, Battle Mountain, Nevada. [242970]
BLM 1998	BLM (Bureau of Land Management), 1998, *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement,* Las Vegas Field Office, U.S. Department of the Interior, Las Vegas, Nevada. [239218, Executive Summary; 239216, Volume 1; 239217, Volume 2]
BLM 1999a	BLM (Bureau of Land Management), 1999a, *Proposed Caliente Management Framework Plan Final Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat,* Ely Field Office, U.S. Department of the Interior, Ely, Nevada. [244133]
BLM 1999b	BLM (Bureau of Land Management), 1999b, *Cortez Gold Mines, Inc. Pipeline Infiltration Project Environmental Assessment,* NV063-EA98-062, NV64-93-00P (98-1A), Battle Mountain District Office, U.S. Department of the Interior, Battle Mountain, Nevada. [243547]
BLS 1998	BLS (Bureau of Labor Statistics), 1998, "Safety and Health Statistics," http://stats.bls.gov/news.release/osh.t01.htm, December 18, U.S. Department of Commerce, Washington, D.C. [243569]

Bodvarsson, Bandurraga, and Wu 1997	Bodvarsson, G. S., T. M. Bandurraga, and Y. S. Wu, editors, 1997, *The Site-Scale Unsaturated Zone Model of Yucca Mountain, Nevada, for the Viability Assessment,* LBNL-40376, Lawrence Berkeley National Laboratory, Berkeley, California. [MOL.19971014.0232]
Bonner et al. 1998	Bonner, L. J., P. E. Elliot, L. P. Etchemendy, and J. R. Swartwood, 1998, *Water Resources Data Nevada Water Year 1997,* WDR-NV-97-1, in cooperation with the State of Nevada and other agencies, Water Resources Division, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [242466]
Bostic et al. 1997	Bostic, R. E., R. L. Kane, K. M. Kipfer, and A. W. Johnson, 1997, *Water Resources Data Nevada Water Year 1996,* WDR-NV-96-1, in cooperation with the State of Nevada and other agencies, Water Resources Division, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [236837]
Brattstrom and Bondello 1983	Brattstrom, B. H., and M. C. Bondello, 1983, "Effects of Off-Road Vehicle Noise on Desert Vertebrates," *Environmental Effects of Off-Road Vehicles, Impacts and Management in Arid Regions,* R. M. Webb and H. G. Wilshire, editors, Springer-Verlag New York, Inc., New York, New York. [221245]
Brown-Buntin 1997	Brown-Buntin Associates, Inc., 1997, *Background Noise Analysis, Proposed Yucca Mountain Nuclear Depository, Nye County, Nevada,* #97-215, Fair Oaks, California. [MOL.19980714.0030]
BTS 1998	BTS (Bureau of Transportation Statistics), 1998, *Bureau of Transportation Statistics, Pocket Guide to Transportation,* BTS98-S-01, U.S. Department of Transportation, Washington, D.C. [243148]
BTS 1999a	BTS (Bureau of Transportation Statistics), 1999a, "Motor Fuel Use – 1996," Table MF-21, http://www.bts.gov/site/news/fhwa/hwy96/section1.html, April 6, Office of Highway Information, U.S. Department of Transportation, Washington, D.C. [244074]
BTS 1999b	BTS (Bureau of Transportation Statistics), 1999b, *National Transportation Statistics 1998* (downloaded from http://www.bts.gov/ntda/nts/nts.html, March 18, 1999), U.S. Department of Transportation, Washington, D.C. [243149]
Buchanan 1997	Buchanan, C. C., 1997, "Final Biological Opinion for Reinitiation of Formal Consultation for Yucca Mountain Site Characterization Studies," letter to W. Dixon (U.S. Department of Energy, Yucca Mountain Site Characterization Office), File No. 1-5-96-F-307R, Fish and Wildlife Service, U.S. Department of the Interior, Nevada State Office, Reno, Nevada. [MOL.19980302.0368]

Buck and Powers 1995	Buck, P., and C. D. Powers, 1995, *Nevada Work Instructions: Archaeological,* Instructions NWI-ARCH 01-08, Yucca Mountain Site Characterization Project, U.S. Department of Energy, Las Vegas, Nevada. [Instruction 01, MOL.19951211.0094; Instruction 02, MOL.19951211.0098; Instruction 03, MOL.19951211.0102; Instruction 04, MOL.19951211.0106; Instruction 05, MOL.19951211.0110; Instruction 06, MOL.19951211.0114; Instruction 07, MOL.19951211.0118; Instruction 08, MOL.19951211.0122]
Bullard 1992	Bullard, K. L., 1992, *Nevada Test Site Probable Maximum Flood Study: Part of a U.S. Geological Survey Flood Potential and Debris Hazard Study, Yucca Mountain Site for United States Department of Energy Office of Civilian Radioactive Waste Management,* Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado. [205030]
Buqo 1996	Buqo, T. S., 1996, *Baseline Water Supply and Demand Evaluation of Southern Nye County, Nevada,* Nye County Nuclear Waste Repository Office, Mercury, Nevada. [235774]
Buqo 1999	Buqo, T. S., 1999, *Nye County Perspective: Potential Impacts Associated With the Long-Term Presence of a Nuclear Repository at Yucca Mountain, Nye County Nevada,* Nye County Nuclear Waste Repository Office, Pahrump, Nevada. [244065]
Bureau of the Census 1992a	Bureau of the Census, 1992a, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244075, p8.; 244083, p12.; 244090, p117.]
Bureau of the Census 1992b	Bureau of the Census, 1992b, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Clark County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244076, p8.; 244084, p12.; 244091, p117.]
Bureau of the Census 1992c	Bureau of the Census, 1992c, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Lincoln County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244077, p8.; 244085, p12.; 244094, p117.]
Bureau of the Census 1992d	Bureau of the Census, 1992d, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Nye County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244078, p8.; 244086, p12.; 244095, p117.]

Bureau of the Census 1992e	Bureau of the Census, 1992e, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Esmeralda County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244079, p8.; 244087, p12.; 244096, p117.]
Bureau of the Census 1992f	Bureau of the Census, 1992f, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Eureka County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244080, p8.; 244088, p12.; 244092, p117.]
Bureau of the Census 1992g	Bureau of the Census, 1992g, "Population and Housing - Detailed Tables: P008 Race-Universe, P012 Hispanic Origin by Race-Universe, P117-Poverty Status in 1989 by Age-Universe: Persons, 1990 Census for Lander County, Nevada," Population Division, U.S. Department of Commerce, Washington, D.C. [244081, p8.; 244089, p12.; 244093, p117.]
Bureau of the Census 1992h	Bureau of the Census, 1992h, *1990 Census Population and Housing, Summary Population and Housing Statistics,* U.S. Report No. 1990 CPH-1-1, U.S. Department of Commerce, Washington, D.C. [235257]
Bureau of the Census 1993	Bureau of the Census, 1993, *Statistical Abstract of the United States 1993,* 113th edition, Economics and Statistics Administration, U.S. Department of Commerce, Washington, D.C. [243008]
Bureau of the Census 1995	Bureau of the Census, 1995, *Statistical Abstract of the United States 1995, The National Data Book,* 115th edition, Economics and Statistics Administration, U.S. Department of Commerce, Washington, D.C. [243747]
Bureau of the Census 1997	Bureau of the Census, 1997, *Statistical Abstract of the United States 1997 – The National Data Book,* 117th edition, Economics and Statistics Administration, U.S. Department of Commerce, Washington, D.C. [8657]
Bureau of the Census 1998	Bureau of the Census, 1998, "1990 Census: Housing Data for Selected Counties in Nevada [Clark, Elko, Esmeralda, Lander, Lincoln, and Nye]," Summary Tape File 3A (STF3A), http://www.venus.census.gov/cdrom/lookup, December 7, Population Division, U.S. Department of Commerce, Washington, D.C. [243201]
Bureau of the Census 1999	Bureau of the Census, 1999, "USA Counties 1996 – Geographic Area: Esmeralda, Nevada, Table: General Profile," http://www.census.gov/statab/USA96/32/009.txt, March 17, Population Division, U.S. Department of Commerce, Washington, D.C. [244007]
Bury and Germano 1994	Bury, R. B., and D. J. Germano, editors, 1994, *Biology of North American Tortoises,* Fish and Wildlife Research Report 13, pp. 57-72, National Biological Survey, U.S. Department of the Interior, Washington, D.C. [225209]

Cappaert v. United States 1976	Cappaert v. United States, 426 U.S. 128 (1976), Cappaert et al. v. United States et al., No. 74-1107, Argued January 12, 1976, Decided June 7, 1976, U.S. Supreme Court, Washington, D.C. [243576]
Carr et al. 1986	Carr, M. D., S. J. Waddell, G. S. Vick, J. M. Stock, S. A. Monsen, A. G. Harris, B. W. Cork, and F. M. Byers, Jr., 1986, *Preliminary Report: Geology of Drillhole UE25p#1: A Test Hole into Pre-Tertiary Rocks Near Yucca Mountain, Southern Nevada,* OFR-86-175, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [HQS.19880517.2633]
CEPA 1998	CEPA (California Environmental Protection Agency), 1998, *Proposed Amendments to the Designation Criteria and to the Area Designations for State Ambient Air Quality Standards and Proposed Maps of the Area Designations for the State and National Ambient Air Quality Standards,* Air Resources Board, Technical Support Division, Sacramento, California. [243397]
CEQ 1997	CEQ (Council on Environmental Quality), 1997, *Considering Cumulative Effects Under the National Environmental Policy Act,* Executive Office of the President, Washington, D.C. [243482]
Cerocke 1998	Cerocke, C., 1998, "Truck Percents," facsimile to R. Best (Jason Technologies Corporation), July 8, Nevada Department of Transportation, Carson City, Nevada. [MOL.19990511.0291]
Chanin and Young 1998	Chanin, D., and M. L. Young, 1998, *Code Manual for MACCS2: Preprocessor Codes for COMIDA2, FGRDCF, IDCF2,* NUREG/CR-6613, SAND97-0594, Volume 2, U.S. Nuclear Regulatory Commission, Washington, D.C. [243881]
Clark County 1997a	Clark County, 1997a, *1996-97 Amended Official Enrollment Count,* Student Record Center, Clark County School District, Las Vegas, Nevada. [241588]
Clark County 1997b	Clark County, 1997b, *Particulate Matter (PM10) Attainment Demonstration Plan, Las Vegas Valley Non-attainment Area, Clark County, Nevada,* Final Report, Clark County Board of Commissioners, Las Vegas, Nevada. [243944]
Clark County 1998	Clark County, 1998, "Amazing Facts, 1997-1998," http://www.ccsd.net/news/geninfo/amazing/amazing.html, April 7, Clark County School District Las Vegas, Nevada. [243963]
Clark County 1999	Clark County, 1999, "Sanitation District Board of Trustees," http//www.sandist.co.clark.nv.us/sandist/aboutus.htm, May 5, Las Vegas, Nevada. [244140]
Clary et al. 1995	Clary, S. L., D. R. McClary, R. Whitney, and D. D. Reeves, 1995, *Water Resources Data for Nevada Water Year 1994,* U.S. Geological Survey, U.S. Department of the Interior, USGS-NV-94-1, Carson City, Nevada. [236835]
Clinch River 1985	Clinch River MRS Task Force, 1985, *Recommendations on the Proposed Monitored Retrievable Storage Facility,* Roane County and City of Oak Ridge, Oak Ridge, Tennessee. [235908]

Covay 1997	Covay, K. J., 1997, "Tables of water-quality data collected May 6-15, 1997," letter with attachments to W. Dixon (U.S. Department of Energy, Yucca Mountain Site Characterization Office), October 6, Nevada District, Water Resources Division, U.S. Geological Survey, U.S. Department of the Interior, Las Vegas, Nevada. [MOL.19981013.0007]
Cowherd, Muleski, and Kinsey 1988	Cowherd, C., G. E. Muleski, and J. S. Kinsey, 1988, *Control of Open Fugitive Dust Sources, Final Report,* pp. 4.1 to 5.41, EPA-450/3-88-008, Midwest Research Institute, Kansas City, Missouri. [243438]
CP&L 1989	CP&L (Carolina Power and Light Company), 1989, *Brunswick Steam Electric Plant Independent Spent Fuel Storage Installation Safety Analysis Report,* Docket No. 50-044, Raleigh, North Carolina. [3933]
CRC 1997	CRC Press, 1997, *CRC Handbook of Chemistry and Physics – A Ready-Reference Book of Chemical and Physical Data,* 78th edition, D. R. Lide, Editor, H.P.R. Frederikse, Associate Editor, Boca Raton, New York. [243741]
Czarnecki 1990	Czarnecki, J. B., 1990, *Geohydrology and Evapotranspiration at Franklin Lake Playa, Inyo County, California,* USGS-OFR-90-356, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [201103]
D'Agnese et al. 1997	D'Agnese, F. A., C. C. Faunt, A. K. Turner, and M. C. Hill, 1997, *Hydrogeologic Evaluation and Numerical Simulation of the Death Valley Regional Ground-Water Flow System, Nevada and California,* WRIR 96-4300, U.S. Geological Survey, U.S. Department of the Interior in cooperation with the U.S. Department of Energy, Denver, Colorado. [MOL.19980306.0253]
D'Azevedo 1986	D'Azevedo, W. L., editor, 1986, "Key to Tribal Territories," Volume 11, *Handbook of North American Indians,* page ix, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C. [243925]
Davies and Archambeau 1997	Davies, J. B., and C. B. Archambeau, 1997, "Geohydrological models and earthquake effects at Yucca Mountain, Nevada," *Environmental Geology,* Volume 32, Number 1, pp. 23-35, New York, New York. [237118]
Davis 1998	Davis, R. G., Jr., 1998, *Direct Exposure from Degrading Commercial Spent Nuclear Fuel Storage,* Tetra Tech NUS, Inc., Aiken, South Carolina. [241173]
Davis, Strenge, and Mishima 1998	Davis, P. R., D. L. Strenge, and J. Mishima, 1998, *Final Accident Analysis for Continued Storage,* Revision 0, Jason Technologies Corporation, Las Vegas, Nevada. [244118]
Day et al. 1996	Day, W. C., C. J. Potter, D. E. Sweetkind, R. P. Dickerson, and C. A. San Juan, 1996, *Bedrock Geologic Map of the Central Block Area, Yucca Mountain, Nye County, Nevada,* map, USGS-MI-2601, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [237019]

Dixon 1999 — Dixon, W. R., 1999, "Renewal Of The State Fire Marshall Hazardous Materials Storage Permit (#13-98-0073-X) And Compliance With The Emergency Planning And Community Right-To-Know Act (EPCRA), Sections 302, 311, And 312," letter to V. A. Cappucci, Office of the State Fire Marshal, State of Nevada, Carson City, Nevada. [MOL.19990329.0386, correspondence; MOL.19990329.0387, permit]

DOE 1980 — DOE (U.S. Department of Energy), 1980, *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste,* DOE/EIS-0046F, Assistant Secretary for Nuclear Energy, Office of Nuclear Waste Management, Washington, D.C. [HQZ.19870302.0183, Volume 1; HQZ.19870302.0184, Volume 2; HQZ.19870302.0185, Volume 3]

DOE 1986a — DOE (U.S. Department of Energy), 1986a, *Nuclear Waste Policy Act (Section 112) Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada,* DOE/RW-0073, Office of Civilian Radioactive Waste Management, Washington, D.C. [HQZ.19870302.0332]

DOE 1986b — DOE (U.S. Department of Energy), 1986b, *Monitored Retrievable Storage Submission to Congress, Environmental Assessment for a Monitored Retrievable Storage Facility,* DOE/RW-0035/1, Office of Civilian Radioactive Waste Management, Washington, D.C. [HQO.19950815.0019]

DOE 1988a — DOE (U.S. Department of Energy), 1988a, *Nuclear Waste Policy Act Section 113 Site Characterization Plan – Yucca Mountain Site, Nevada Research and Development Area, Nevada,* DOE/RW-0199, Office of Civilian Radioactive Waste Management, Washington, D.C. [HQO.19881201.0002]

DOE 1988b — DOE (U.S. Department of Energy), 1988b, *Programmatic Agreement Between the United States Department of Energy and the Advisory Council on Historic Preservation for the Nuclear Waste Deep Geologic Repository Program, Yucca Mountain, Nevada,* Yucca Mountain Site Characterization Office, Nevada Operations Office, North Las Vegas, Nevada. [HQX.19890426.0057]

DOE 1989a — DOE (U.S. Department of Energy), 1989a, *Draft Reclamation Program Plan for Site Characterization,* DOE/RW-0244, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Washington, D.C. [HQO.19890803.0001]

DOE 1989b — DOE (U.S. Department of Energy), 1989b, *MRS System Study Summary Report,* DOE/RW-0235, Office of Civilian Radioactive Waste Management, Washington, D.C. [HQO.19890602.0001]

DOE 1990 — DOE (U.S. Department of Energy), 1990, *Research Design and Data Recovery Plan for the Yucca Mountain Project – Permanent Copy,* Yucca Mountain Project Office, Las Vegas, Nevada. [NNA.19910107.0105]

DOE 1991a	DOE (U.S. Department of Energy), 1991a, *Site Characterization Progress Report: Yucca Mountain, Nevada, October 1, 1990 – March 31, 1991, Number 4, October 1991,* DOE/RW-0307P-4, Office of Civilian Radioactive Waste Management, Washington, D.C. [HQO.19910904.0001]
DOE 1991b	DOE (U.S. Department of Energy), 1991b, *The Nevada Railroad System: Physical, Operational, and Accident Characteristics,* YMP-91-19, Office of Civilian Radioactive Waste Management, Las Vegas, Nevada. [NNA.19920608.0151]
DOE 1992a	DOE (U.S. Department of Energy), 1992a, *Environmental Field Activity Plan for Archaeological Resources,* Yucca Mountain Site Characterization Project, Las Vegas, Nevada. [NNA.19921027.0021]
DOE 1992b	DOE (U.S. Department of Energy), 1992b, *Environmental Assessment for the Shipment of Low Enriched Uranium Billets to the United Kingdom from the Hanford Site, Richland, Washington,* DOE/EA--0787, Richland, Washington. [242983]
DOE 1994a	DOE (U.S. Department of Energy), 1994a, *Final Supplemental Environmental Impact Statement, Defense Waste Processing Facility,* DOE/EIS-0082-S, Savannah River Operations Office, Aiken, South Carolina. [243608]
DOE 1994b	DOE (U.S. Department of Energy), 1994b, *Yucca Mountain Site Characterization Project Socioeconomic Monitoring Program 1994, U.S. Department of Energy/Nevada Survey of Yucca Mountain Site Characterization Project Workforce State and County Data,* Las Vegas, Nevada. [MOL.19941214.0038]
DOE 1994c	DOE (U.S. Department of Energy), 1994c, *Radiological Control Manual,* April 1994, Chapters 1-7, DOE/EH-0256T, Revision 1, Assistant Secretary for Environment, Safety and Health, Washington, D.C. [MOL.19950130.0075]
DOE 1994d	DOE (U.S. Department of Energy), 1994d, *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics,* DOE/LLW-114, Revision 1, Idaho National Engineering Laboratory, Idaho Falls, Idaho. [231330]
DOE 1995a	DOE (U.S. Department of Energy), 1995a, *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs: Final Environmental Impact Statement,* DOE/EIS-0203-F, Office of Environmental Management, Idaho Operations Office, Idaho Falls, Idaho. [102617]
DOE 1995b	DOE (U.S. Department of Energy), 1995b, *Record of Decision Department of Energy Programmatic Spent Nuclear Fuel Management and the Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs,* Office of Environmental Management, Idaho Operations Office, Idaho Falls, Idaho. [243787]

DOE 1995c — DOE (U.S. Department of Energy), 1995c, *Savannah River Site Waste Management Final Environmental Impact Statement,* DOE/EIS-0217, Savannah River Operations Office, Aiken, South Carolina. [243607]

DOE 1995d — DOE (U.S. Department of Energy), 1995d, *Final Environmental Impact Statement, Interim Management of Nuclear Materials: Savannah River Site, Aiken, South Carolina,* DOE/EIS-0220, Savannah River Operations Office, Aiken, South Carolina. [243411]

DOE 1995e — DOE (U.S. Department of Energy), 1995e, *Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling Executive Summary,* DOE/EIS-0161, Office of Reconfiguration, Washington, D.C. [243898]

DOE 1995f — DOE (U.S. Department of Energy), 1995f, *Final Environmental Assessment for Solid Waste Disposal, Nevada Test Site, Nye County, Nevada, August 1995, including a finding of no significant impact,* DOE/EA-1097, Nevada Operations Office, Las Vegas, Nevada. [235646]

DOE 1995g — DOE (U.S. Department of Energy), 1995g, *Reclamation Implementation Plan,* YMP/91-14, Revision 1, Las Vegas, Nevada. [MOL.19960222.0218]

DOE 1995h — DOE (U.S. Department of Energy), 1995h, *Environmental Assessment: Disposition and Transportation of Surplus Radioactive Low Specific Activity Nitric Acid, Hanford Site, Richland, Washington,* DOE/EA-1005, Washington, D.C. [242982]

DOE 1996a — DOE (U.S. Department of Energy), 1996a, *Addendum (Final Environmental Impact Statement): Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington,* DOE/EIS-0245-F, Richland Operations Office, Richland, Washington. [243958]

DOE 1996b — DOE (U.S. Department of Energy), 1996b, *Draft Environmental Impact Statement for Completion of the West Valley Demonstration Project and Closure of Long-Term Management Facilities at the Western New York Nuclear Service Center,* DOE/EIS-0226-D, in cooperation with the New York State Energy Research and Development Authority, West Valley Area Office, West Valley, New York. [223997]

DOE 1996c — DOE (U.S. Department of Energy), 1996c, *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel,* DOE/EIS-0218F, Assistant Secretary for Environmental Management, Washington, D.C. [223998]

DOE 1996d — DOE (U.S. Department of Energy), 1996d, *Final Environmental Impact Statement for the Tank Waste Remediation System, Hanford Site, Richland, Washington,* DOE/EIS-0189, in cooperation with the Washington State Department of Ecology, Richland Operations Office, Richland, Washington. [226909]

DOE 1996e	DOE (U.S. Department of Energy), 1996e, *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement,* DOE/EIS-0229, Office of Fissile Materials Disposition, Washington, D.C. [243896, Summary; 243897, Volumes 1 and 2]
DOE 1996f	DOE (U.S. Department of Energy), 1996f, *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada,* DOE/EIS-0243-F, Nevada Operations Office, Las Vegas, Nevada. [239895]
DOE 1996g	DOE (U.S. Department of Energy), 1996g, *Yucca Mountain Project Stratigraphic Compendium and Plate 1 – Characteristics of Surficial Geologic Units in the Vicinity of Yucca Mountain,* BA0000000-01717-5700-00004, Revision 01, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19970113.0088]
DOE 1996h	DOE (U.S. Department of Energy), 1996h, *Yucca Mountain Site Characterization Project Regulated Materials Management Plan,* YMP/91-35, Revision 1, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, Las Vegas, Nevada. [MOL.19960722.0079]
DOE 1996i	DOE (U.S. Department of Energy), 1996i, *Report on the Status of the Final 1995 RW-859 Data Set,* Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, Las Vegas, Nevada. [MOV.19960816.0008]
DOE 1996j	DOE (U.S. Department of Energy), 1996j, *Medical Isotopes Production Project: Molybdenum-99 and Related Isotopes, Environmental Impact Statement,* DOE/EIS-0249F, Washington, D.C. [232857]
DOE 1996k	DOE (U.S. Department of Energy), 1996k, *Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement,* DOE/EIS-0240, Washington, D.C. [231278]
DOE 1996l	DOE (U.S. Department of Energy), 1996l, *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management,* DOE/EIS-0236, Washington, D.C. [226584]
DOE 1996m	DOE (U.S. Department of Energy), 1996m, *Final Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components,* DOE/EIS-0225, Washington, D.C. [242979]
DOE 1996n	DOE (U.S. Department of Energy), 1996n, *Final Environmental Impact Statement S1C Prototype Reactor Plant Disposal,* DOE/EIS-0275, Office of Naval Reactors, Windsor, Connecticut. [242980]

DOE 1997a	DOE (U.S. Department of Energy), 1997a, *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office, North Las Vegas, Nevada. [MOL.19970731.0515]
DOE 1997b	DOE (U.S. Department of Energy), 1997b, *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste,* DOE/EIS-0200-F, Office of Environmental Management, Washington, D.C. [232988]
DOE 1997c	DOE (U.S. Department of Energy), 1997c, "Location of Alternative Heavy-Haul Routes and Future Las Vegas Beltway," map, YMP-97-262.0, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990610.0306]
DOE 1997d	DOE (U.S. Department of Energy), 1997d, *Intermodal Transfer Station Preliminary Design,* BCBI00000-01717-0200-00007, Revision 00, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19980303.0029]
DOE 1997e	DOE (U.S. Department of Energy), 1997e, *Regional Groundwater Flow and Tritium Transport Modeling and Risk Assessment of the Underground Test Area, Nevada Test Site, Nevada,* DOE/NV-477, Nevada Operations Office, Las Vegas, Nevada. [243999]
DOE 1997f	DOE (U.S. Department of Energy), 1997f, *Soil Types within the Busted Butte USGS 7.5-Minute Quadrangle,* YMP/97-008.1, Office of Civilian Radioactive Waste Management, Yucca Mountain Project, Las Vegas, Nevada. [MOL.19990610.0224]
DOE 1997g	Intentionally omitted.
DOE 1997h	DOE (U.S. Department of Energy), 1997h, *Waste Minimization and Pollution Prevention Awareness Plan, Approved,* YMP/95-01, Revision 1, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19980224.0441]
DOE 1997i	DOE (U.S. Department of Energy), 1997i, *Determination of Importance Evaluation for the Surface Exploratory Studies Facility,* BAB000000-01717-2200-00106, Revision 02, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19971001.0281]
DOE 1997j	DOE (U.S. Department of Energy), 1997j, *Determination of Importance Evaluation for the Subsurface Exploratory Studies Facility,* BAB000000-01717-2200-00005, Revision 06, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19971001.0663]

DOE 1997k	DOE (U.S. Department of Energy), 1997k, *Land Withdrawal Area,* map, YMP-97-317.0, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990602.0178]
DOE 1997l	DOE (U.S. Department of Energy), 1997l, *Secondary Waste Treatment Analysis,* BCBD00000-01717-0200-00005, Revision 00, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19971208.0201]
DOE 1997m	DOE (U.S. Department of Energy), 1997m, *DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities,* BCA000000-01717-0200-00017, Revision 00, Office of Civilian Radioactive Waste Management, Las Vegas, Nevada. [MOL.19980218.0237]
DOE 1997n	DOE (U.S. Department of Energy), 1997n, *Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials, Final Programmatic Environmental Impact Statement,* Washington, D.C. [239425]
DOE 1997o	DOE (U.S. Department of Energy), 1997o, *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement,* DOE/EIS-0026-S-2, Carlsbad Area Office, Carlsbad, New Mexico. [238195]
DOE 1997p	DOE (U.S. Department of Energy), 1997p, *Integrated Data Base for 1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* DOE/RW-0006, Revision 13, Office of Environmental Management, Oak Ridge National Laboratories, Oak Ridge, Tennessee. [242471]
DOE 1997q	DOE (U.S. Department of Energy), 1997q, *Final Environmental Impact Statement, Disposal of the S3G and D1G Prototype Reactor Plants,* DOE/EIS-0274, Office of Naval Reactors, Schenectady, New York. [242981]
DOE 1998a	DOE (U.S. Department of Energy), 1998a, *Viability Assessment of a Repository at Yucca Mountain,* DOE/RW-0508, Office of Civilian Radioactive Waste Management, Washington, D.C. [U.S. Government Printing Office, MOL.19981007.0027, Overview; MOL.19981007.0028, Volume 1; MOL.19981007.0029, Volume 2; MOL.19981007.0030, Volume 3; MOL.19981007.0031, Volume 4; MOL.19981007.0032, Volume 5]
DOE 1998b	DOE (U.S. Department of Energy), 1998b, *Surplus Plutonium Disposition Draft Environmental Impact Statement,* DOE/EIS-0283-D, Office of Fissile Materials Disposition, Washington, D.C. [243236]
DOE 1998c	DOE (U.S. Department of Energy), 1998c, *Savannah River Site Spent Nuclear Fuel Management Draft Environmental Impact Statement,* DOE/EIS-0279-D, Savannah River Operations Office, Aiken, South Carolina. [243456]

DOE 1998d — DOE (U.S. Department of Energy), 1998d, "Nevada Routes for Legal-Weight Truck Shipments of SNF and HLW to Yucca Mountain," map, YMP-97-310.3, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990526.0033]

DOE 1998e — DOE (U.S. Department of Energy), 1998e, "Potential Rail Corridors," map, YMP-98-179.0, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990526.0032]

DOE 1998f — DOE (U.S. Department of Energy), 1998f, "Potential Rail Alignments," map, YMP-98-104.0, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990526.0034]

DOE 1998g — DOE (U.S. Department of Energy), 1998g, "Nevada Routes for Heavy-Haul Truck Shipments of SNF and HLW to Yucca Mountain," map, YMP 97-263.9, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990526.0035]

DOE 1998h — DOE (U.S. Department of Energy), 1998h, *Disturbances at Yucca Mountain Since June 21, 1991,* map, YMP-97-160.2, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990610.0319]

DOE 1998i — DOE (U.S. Department of Energy), 1998i, *Existing Pre-Repository Site Conditions,* Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990513.0044]

DOE 1998j — DOE (U.S. Department of Energy), 1998j, "Intermodal Transfer Site – Caliente Siting Area Map," BCBI00000-01717-2700-82038, Revision 00, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990615.0031]

DOE 1998k — DOE (U.S. Department of Energy), 1998k, *Emergency Management Plan,* YMP/92-38, Revision 3, Yucca Mountain Site Characterization Project, Office of Civilian Radioactive Waste Management, Las Vegas, Nevada. [MOL.19980921.0373]

DOE 1998l — DOE (U.S. Department of Energy), 1998l, *The Current and Planned Low-Level Waste Disposal Capacity Report, Revision 1,* Office of Environmental Management, Washington, D.C. [243825]

DOE 1998m — DOE (U.S. Department of Energy), 1998m, *Intermodal Transportation of Low-level Radioactive Waste to the Nevada Test Site, Preapproval Draft Environmental Assessment,* Nevada Operations Office, Las Vegas, Nevada. [243941]

DOE 1998n — DOE (U.S. Department of Energy), 1998n, *Nevada Test Site Resource Management Plan,* DOE/NV-518, Nevada Operations Office, Las Vegas, Nevada. [244395]

DOE 1998o	DOE (U.S. Department of Energy), 1998o, *Summary of the DOE/NRC Technical Exchange on Total System Performance Assessment – Viability Assessment, March 17-19, 1998,* Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19980701.0025]
DOE 1998p	DOE (U.S. Department of Energy), 1998p, *Centralized Interim Storage Facility Topical Safety Analysis Report,* Revision 1, Volumes I and II, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990212.0117]
DOE 1999a	DOE (U.S. Department of Energy), 1999a, *Reference Design Description for a Geologic Repository,* B00000000-01717-5707-00002, Revision 2, Office of Civilian Radioactive Waste Management, Yucca Mountain Project Office, Las Vegas, Nevada. [MOL.19990301.0225]
DOE 1999b	DOE (U.S. Department of Energy), 1999b, *Supplement to the Surplus Plutonium Disposition Draft Environmental Impact Statement,* DOE/EIS-0283-DS, Office of Fissile Materials Disposition, Washington, D.C. [244066]
DOE 1999c	DOE (U.S. Department of Energy), 1999c, "CAIRS Database, DOE and Contractor Injury and Illness Experience by Operation Type by Year and Quarter, 1993 through 1998," http://tis.eh.doe.gov/cairs/cairs/dataqtr/q984a.htm, May 22, Washington, D.C. [244036]
DOE 1999d	Intentionally omitted.
DOE 1999e	DOE (U.S. Department of Energy), 1999e, *Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at the INEEL,* DOE/ID-10636, Idaho Operations Office, Idaho Falls, Idaho. [244067]
DOE 1999f	DOE (U.S. Department of Energy), 1999f, *Record of Decision for a Multi-Purpose Canister or Comparable System for Idaho National Engineering and Environmental Laboratory Spent Nuclear Fuel,* Office of the Assistant Secretary for Environmental Management, Washington, D.C. [244224]
DOE 1999g	DOE (U.S. Department of Energy), 1999g, *Final Environmental Impact Statement: Accelerator Production of Tritium at the Savannah River Site,* DOE/EIS-0270F, Savannah River Operations Office, Aiken, South Carolina. [243880, Draft; 244215, Update]
Dublyansky 1998	Dublyansky, Y. V., 1998, *Fluid inclusion studies of samples from the Exploratory Study Facility, Yucca Mountain, Nevada,* Institute for Energy and Environmental Research, Takoma Park, Maryland. [HQO.19990201.0012]
Dudley and Larson 1976	Dudley, W. W., Jr., and J. D. Larson, 1976, *Effect of Irrigation Pumping on Desert Pupfish Habitats in Ash Meadows, Nye County, Nevada,* Professional Paper 927, U.S. Geological Survey, U.S. Department of the Interior, Washington, D.C. [219489]

Eckerman and Ryman 1993	Eckerman, K. F., and J. C. Ryman, 1993, *External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance: Federal Guidance Report No. 12,* EPA 402-R-93-081, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington D.C. [225472]
Eckerman, Wolbarst, and Richardson 1988	Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson, 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,* Federal Guidance Report No. 11, EPA-520/1-88-020, U.S. Environmental Protection Agency, Office of Radiation Programs, Oak Ridge National Laboratory, Oak Ridge, Tennessee. [203350]
Elston 1986	Elston, R. B., 1986, "Prehistory of the Western Area," Volume 11, *Handbook of North American Indians,* pp. 135-148, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C. [243924]
EPA 1974	EPA (U.S. Environmental Protection Agency), 1974, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety,* Report 550/9-74-004, Office of Noise Abatement and Control, Arlington, Virginia. [221144]
EPA 1993	EPA (U.S. Environmental Protection Agency), 1993, *Drinking Water Regulations and Health Advisories,* Washington, D.C. [NNA.19940510.0010]
EPA 1995	EPA (U.S. Environmental Protection Agency), 1995, *User's Guide for Industrial Source Complex (ISC3) Dispersion Models,* EPA-454/B-95-003a, Emissions, Monitoring, and Analysis Division, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. [243563]
EPA 1996a	EPA (U.S. Environmental Protection Agency), 1996a, *Ambient Levels and Noncancer Health Effects of Inhaled Crystalline and Amorphous Silica: Health Issue Assessment,* EPA/600/R-95/115, National Center for Environmental Assessment, Office of Research and Development, Washington, D.C. [243562]
EPA 1996b	EPA (U.S. Environmental Protection Agency), 1996b, *National Capacity Assessment Report: Capacity Planning Pursuant to CERCLA Section 104(c)(9),* EPA530-R-95-016, Office of Solid Waste, Washington, D.C. [242975]
EPA 1997a	EPA (U.S. Environmental Protection Agency), 1997a, *Technical Highlights: Emission Factors for Locomotives,* EPA420-F-97-051, Office of Mobile Sources, Ann Arbor, Michigan. [243739]
EPA 1997b	EPA (U.S. Environmental Protection Agency), 1997b, *Locomotive Emission Standards, Regulatory Support Document,* Abridged Version, Office of Mobile Sources, Washington, D.C. [244069]
EPA 1998a	EPA (U.S. Environmental Protection Agency), 1998a, *Toxicological Review of Hexavalent Chromium (CAS No. 18540-29-9),* Washington, D.C. [243147]

EPA 1998b — EPA (U.S. Environmental Protection Agency), 1998b, "U.S. EPA Mixed Waste Team Homepage," http://www.epa.gov/radiation/mixed-waste/mw_pg11a.htm, December 14, Washington, D.C. [243245]

EPA 1999a — EPA (U.S. Environmental Protection Agency), 1999a, "Nevada Class I Areas," http://www.epa.gov/region09/air/maps/r9_no2.html, March 18, Washington, D.C. [243566]

EPA 1999b — EPA (U.S. Environmental Protection Agency), 1999b, "California Federal Class I Areas," http://www.epa.gov/region09/air/maps/, March 18, Washington, D.C. [243573]

EPA 1999c — EPA (U.S. Environmental Protection Agency), 1999c, "Region 9," http://www.epa.gov/region09/air/maps/r9_o3.html, r9_co.html, r9_pm10.html, r9_no2.html, March 18, Washington, D.C. [243571; 243565; 243567; 243572]

EPA 1999d — EPA (U.S. Environmental Protection Agency), 1999d, "Uranium, natural, CASRN 7440-61-1," http://www.epa.gov/iris/subst/0259.htm, June 10, Office of Research and Development, National Center for Environmental Assessment, Cincinnati, Ohio. [244072]

ETS 1989 — ETS Pacific, Inc., 1989, *Evaluate Alternative Rail Corridor Routes Through Lincoln Co., NV, to Yucca Mountain, NV,* Portland, Oregon. [NNA.19890828.0036]

Fabryka-Martin et al. 1998 — Fabryka-Martin, J. T., A. V. Wolfsberg, S. S. Levy, K. Campbell, P. Tseng, J. L. Roach, and L. E. Wolfsberg, 1998, *Evaluation of Flow and Transport Models of Yucca Mountain, Based on Chlorine-36 and Chloride Studies for FY98,* BA0000000-01717-5700-00007, Revision 00, TRW Environmental Safety Systems Inc. and Los Alamos National Laboratory, Las Vegas, Nevada, and Albuquerque, New Mexico. [MOL.19981208.0119]

FBI 1996 — FBI (Federal Bureau of Investigation), 1996, "Uniform Crime Reporting Program Press Release" (downloaded from http://www.fbi.gov/ucr/ucr95prs.htm, April 8), October 16, U.S. Department of Justice, Washington, D.C. [243835]

FEMA 1988a — FEMA (Federal Emergency Management Agency), 1988a, *Flood Insurance Rate Map (FIRM), Lincoln County, Nevada (Unincorporated Areas),* Panel 3006 of 5525, Community-Panel Number 320014 3006 C, Washington, D.C. [243867]

FEMA 1988b — FEMA (Federal Emergency Management Agency), 1988b, *Flood Insurance Rate Map (FIRM), Lincoln County, Nevada,* Panel 3008 of 5525, Community-Panel Number 320014 3008 C, Washington, D.C. [243866]

FEMA 1995a — FEMA (Federal Emergency Management Agency), 1995a, *Flood Insurance Rate Map (FIRM), Clark County, Nevada, and Incorporated Areas,* Panel 3125 of 4090, Map Number 32003C3125 D, Washington, D.C. [243864]

FEMA 1995b	FEMA (Federal Emergency Management Agency), 1995b, *Flood Insurance Rate Map (FIRM), Clark County, Nevada, and Incorporated Areas,* Map Index, Map Number 32003C0000, Washington, D.C. [244000]
FEMA 1995c	FEMA (Federal Emergency Management Agency), 1995c, *Flood Insurance Rate Map (FIRM), Clark County, Nevada, and Incorporated Areas,* Panel 1450 of 4090, Map Number 32003C1450 D, Washington, D.C. [243865]
FHWA 1996	FHWA (Federal Highway Administration), 1996, *Northern & Western Las Vegas Beltway, Clark County, Nevada: Tier 1 Final Environmental Impact Statement and Corridor Location Study,* FHWA-NV-EIS-95-01-F, U.S. Department of Transportation, Carson City, Nevada. [242309]
Fischer et al. 1987	Fischer, L. E., C. K. Chou, M. A. Gerhard, C. Y. Kimura, R. W. Martin, R. W. Mensing, M. E. Mount, and M. C. Witte, 1987, *Shipping Container Response to Severe Highway and Railway Accident Conditions,* NUREG/CR-4829, Lawrence Livermore National Laboratory, Livermore, California. [NNA.19900827.0230, main document; NNA.19900827.0231, appendixes]
Flint, Hevesi, and Flint 1996	Flint, A. L., J. A. Hevesi, and L. E. Flint, 1996, *Draft Conceptual and Numerical Model of Infiltration for the Yucca Mountain Area, Nevada,* in cooperation with the Nevada Operations Office, U.S. Department of Energy, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [MOL.19970409.0087]
Fosmire 1999	Fosmire, C., 1999, "Location of Sloan and Apex IMT with respect to LV Air Basin," electronic communication to J. Jessen (Jason Technologies Corporation), TRW Environmental Safety Systems Inc., Las Vegas, Nevada. [MOL.19990511.0376]
Fowler and Madsen 1986	Fowler, D. D., and D. B. Madsen, 1986, "Prehistory of the Southeastern Area," Volume 11, *Handbook of North American Indians,* pp. 173-182, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C. [243926]
Fowler et al. 1973	Fowler, D. D., D. B. Madsen, E. M. Hattori, F. W. Sharrock, H. C. Cutler, and L. W. Blake, 1973, *Prehistory of Southeastern Nevada,* Desert Research Institute Publications in the Social Sciences, No. 6, Reno, Nevada. [243691]
FWS 1996	FWS (Fish and Wildlife Service), 1996, *Railroad Valley Springfish,* Crenichthys nevadae, *Recovery Plan,* U.S. Department of the Interior, Region 1, Portland, Oregon. [241499]
FWS 1998	FWS (Fish and Wildlife Service), 1998, *Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley,* Region 1, U.S. Department of the Interior, Portland, Oregon. [240435]
Geomatrix and TRW 1996	Geomatrix and TRW (Geomatrix Consultants, Inc., and TRW Environmental Safety Systems Inc.), 1996, *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada,* BA0000000-01717-2200-00082, Revision 0, San Francisco, California. [MOL.19961119.0034]

Geomatrix and TRW 1998	Geomatrix and TRW (Geomatrix Consultants, Inc., and TRW Environmental Safety Systems Inc.), 1998, *Saturated Zone Flow and Transport Expert Elicitation Project,* San Francisco, California, and Las Vegas, Nevada. [MOL.19980825.0008]
Hansen et al. 1997	Hansen, D. J., P. D. Greger, C. A. Wills, and W. K. Ostler, 1997, *Nevada Test Site Wetlands Assessment,* DOE/NV/11718-124, Ecological Services, Bechtel Nevada Corporation, Las Vegas, Nevada. [242338]
Hanson, Saurenman, and Towers 1991	Hanson, C. E., H. J. Saurenman, and D. A. Towers, 1991, "Rail Transportation Noise and Vibration," Chapter 46, *Handbook of Acoustical Measurements and Noise Control, Third Edition,* C. M. Harris, editor, McGraw-Hill, Inc., New York, New York. [244002]
Harge 1997	Harge, Geraldine M., 1997, "A Message from the Nye County Superintendent of Schools, Geraldine Harge," *Pahrump Valley Magazine,* Eighth Annual Edition, p. 18, Pahrump Valley Chamber of Commerce, Pahrump, Nevada. [242669]
Harrill, Gates, and Thomas 1988	Harrill, J. R., J. S. Gates, and J. M. Thomas, 1988, "Major Ground-Water Flow Systems in the Great Basin Region of Nevada, Utah and Adjacent States (Map)," *U.S. Geological Survey Hydrologic Investigations Atlas,* HA-694-C, Reston, Virginia. [239034]
Harris 1997	Harris, M. W., 1997, "Summary of Waste Management Activities by the Yucca Mountain Site Characterization Project (YMP) for Calendar Years 1995, 1996," letter to W. Dixon (Yucca Mountain Site Characterization Office, U.S. Department of Energy), July 1, TRW Environmental Safety Systems Inc., Las Vegas, Nevada. [MOL.19971121.0071, correspondence; MOL.19971121.0072, attachment]
Harris 1998	Harris, M. W., 1998, "Transmittal of Biennial Hazardous Waste Report," letter to W. R. Dixon (Yucca Mountain Site Characterization Office, U.S. Department of Energy), January 29, TRW Environmental Safety Systems Inc., Las Vegas, Nevada. [MOL.19980421.0346, correspondence; MOL.19980421.0347, attachment]
Henderson 1997	Henderson, Charles R., Major General, USAF, 1997, "Offer to Meet and Discuss Potential Transport of Spent Fuel to Yucca Mountain," letter to R. Guida (Naval Nuclear Propulsion Program), Director of Operations and Training, DCS/Air and Space Operations, U.S. Department of the Air Force, Washington, D.C. [MOL.19990303.0505]
Hillner, Franklin, and Smee 1998	Hillner, E., D. G., Franklin, and J. D. Smee, 1998, *The Corrosion of Zircaloy-Clad Fuel Assemblies in a Geologic Repository Environment,* WAPD-T-3173, Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania. [237127]
Holmes & Narver 1962	Holmes & Narver, Inc., 1962, *Feasibility Study for Transportation Facilities to Nevada Test Site,* Los Angeles, California. [MOL.19950509.0039]

Horton 1997	Horton, G., 1997, "Repository EIS Contact Report to Collect Information About Water Use in Clark County, Lincoln, and Nye Counties," facsimile to S. LeStrange (Science Applications International Corporation), November 12, Nevada Division of Water Planning, Carson City, Nevada. [MOL.19990513.0046]
Hoskins 1990	Hoskins, R. E., 1990, *Nuclear Waste Management Systems Issues Related to Transportation Cask Design: At-Reactor Spent Fuel Storage, Monitored Retrievable Storage and Modal Mix,* NWPO-TN-003-90, State of Nevada Agency for Nuclear Waste Projects, Nuclear Waste Project Office, Carson City, Nevada. [NNA.19910510.0131]
Houghton, Sakamoto, and Gifford 1975	Houghton, J. G., C. M. Sakamoto, and R. O. Gifford, 1975, *Nevada's Weather and Climate,* Special Publication No. 2, Nevada Bureau of Mines and Geology and MacKay School of Mines, University of Nevada-Reno, Reno, Nevada. [225666]
House 1999	House, K., 1999, "Cask Fleet for Disposal Container and Shipping Cask Analysis," internal memorandum to R. Best, February 23, Jason Technologies Corporation, Las Vegas, Nevada. [MOL.19990511.0378]
Humphreys, Rollstin, and Ridgely 1997	Humphreys, S. L., J. A. Rollstin, and J. N. Ridgely, 1997, *SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program,* NUREG/CR-6525, SAND93-4032, Sandia National Laboratories, Albuquerque, New Mexico, for Division of Systems Technology, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington D.C. [241168]
IAEA 1992	IAEA (International Atomic Energy Agency), 1992, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards,* Technical Reports Series No. 332, Vienna, Austria. [243768]
IARC 1987	IARC (International Agency for Research on Cancer), 1987, *Silica and Some Silicates,* World Health Organization, United Nations, Lyon, France. [226502]
IARC 1997	IARC (International Agency for Research on Cancer), 1997, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Silica, Some Silicates, Coal Dust and* para-*Aramid Fibrils, Volume 68,* IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, World Health Organization, United Nations, Lyon, France. [236833]
ICC 1992	ICC (Interstate Commerce Commission), 1992, *Draft Environmental Impact Statement, Finance Docket No. 30186 (Sub-No. 2), Tongue River Railroad Company – Construction and Operation of an Additional Rail Line from Ashland to Decker, Montana,* Section of Energy and Environment, Office of Economics, Washington, D.C. [MOL.19990511.0395]
ICRP 1991	ICRP (International Commission on Radiological Protection), 1991, *1990 Recommendations of the International Commission on Radiological Protection,* Publication 60, Volume 21, Numbers 1-3, Pergamon Press, Elmsford, New York. [235864]

ICRP 1994	ICRP (International Commission on Radiological Protection), 1994, *Protection Against Radon-222 at Home and at Work,* Publication 65, Pergamon Press, Oxford, Great Britain. [236754]
JAI 1996	JAI Corporation, 1996, *Shipping and Storage Cask Data For Commercial Spent Nuclear Fuel,* Fairfax, Virginia. [232956]
Jarzemba, LaPlante, and Poor 1997	Jarzemba, M. S., P. A. LaPlante, and K. J. Poor, 1997, *ASHPLUME Version 1.0 — A Code for Contaminated Ash Dispersal and Deposition, Technical Description and User's Guide,* 97-004, Revision 1, Center for Nuclear Waste Regulatory Analyses, San Antonio, Texas. [239303]
Jessen 1998	Jessen, J., 1998, "Additional Land Disturbance at Yucca Mountain from Repository Construction (Base Case and Extended Inventory)," internal memorandum, July 23, Jason Technologies Corporation, Las Vegas, Nevada. [MOL.19990602.0181]
Jessen 1999a	Jessen, J., 1999a, "Final Closure Phase Years based on March 99 EF's," electronic communication to Ikenberry et al., Jason Technologies Corporation, Las Vegas, Nevada. [MOL.19990526.0030]
Jessen 1999b	Jessen, J., 1999b, "Corrected: Closure Durations for EIS analysis," internal electronic communication to L. Kripps et al., January 12, Jason Technologies Corporation, Las Vegas, Nevada. [MOL.19990511.0389]
Johnson et al. 1993a	Johnson, P. E., D. S. Joy, D. B. Clarke, and J. M. Jacobi, 1993a, *HIGHWAY 3.1 - An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual,* Revision 1, ORNL/TM-12124, Oak Ridge National Laboratory, Oak Ridge, Tennessee. [MOV.19960711.0024]
Johnson et al. 1993b	Johnson, P. E., D. S. Joy, D. B. Clarke, and J. M. Jacobi, 1993b, *INTERLINE 5.0 - An Expanded Railroad Routing Model: Program Description, Methodology, and Revised User's Manual,* ORNL/TM-12090, Oak Ridge National Laboratory, Oak Ridge, Tennessee. [MOV.19960711.0014]
Kappes 1998	Kappes, J. A., 1998, *Preliminary Preclosure Design Basis Event Calculations for the Monitored Geologic Repository,* BC0000000-01717-0200-0001, Revision 00A, TRW Environmental Safety Systems Inc., Las Vegas, Nevada. [MOL.19981002.0001]
Karl 1980	Karl, A. E., 1980, "Distribution and Relative Densities of the Desert Tortoise in Nevada," *Proceedings of the Desert Tortoise Council Symposium, 1980,* pp. 75-87, Desert Tortoise Council, Long Beach, California. [240684]
Karl 1981	Karl, A. E., 1981, "Distribution and Relative Densities of the Desert Tortoise, *Gopherus agassizii,* in Lincoln and Nye Counties, Nevada," *Proceedings of the Desert Tortoise Council Symposium, 1981,* pp. 76-92, Bureau of Land Management, U.S. Department of the Interior, Denver, Colorado. [243166]
Kautz and Oothoudt 1992	Kautz, R. R., and J. W. Oothoudt, 1992, *A Cultural Resources Survey of the Caliente Wastewater Treatment Project, Lincoln County, Nevada,* Project #827, Mariah Associates, Inc., Reno, Nevada. [243954]

Kelderhouse 1999	Kelderhouse, S., 1999, "LWT, HH and Rail transportation graphics," electronic communication with attachment to R. Best (Jason Technologies Corporation), JAI Corporation, Las Vegas, Nevada. [MOL.19990526.0027]
Kersting et al. 1999	Kersting, A. B., D. W. Efurd, D. L. Finnegan, D. J. Rokop, D. K. Smith, and J. L. Thompson, 1999, "Migration of plutonium in ground water at the Nevada Test Site," *Nature,* Volume 397, pp. 56 to 59, January 7, Macmillan Publishers, Great Britain. [243597]
Kiewit 1997	Kiewit/Parsons Brinkerhoff, 1997, *Spill Prevention, Control, and Countermeasures Plan for Construction and Other Activities,* BAB000000-01717-6300-01600-CD-01-4, Revision 4, Las Vegas, Nevada. [MOL.19971226.0530]
Koppenaal 1998a	Koppenaal, T., 1998a, "Surface EF Question," memorandum to M. Hoganson (Tetra Tech NUS, Inc.), April 6, Science Applications International Corporation, Las Vegas, Nevada. [MOL.19990511.0381]
Koppenaal 1998b	Koppenaal, T., 1998b, "Waste Questions," memorandum to M. Hoganson (Tetra Tech NUS, Inc.), April 30, Science Applications International Corporation, Las Vegas, Nevada. [MOL.19990511.0380]
La Camera and Locke 1997	La Camera, R. J., and G. L. Locke, 1997, *Selected Ground-Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, Through December 1996,* OFR-97-821, in cooperation with the Nevada Operations Office of the U.S. Department of Energy, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [236683]
La Camera, Locke, and Munson 1999	La Camera, R. J., G. L. Locke, and R. N. Munson, 1999, *Selected Ground-Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, Through December 1997,* OFR-98-628, in cooperation with the Nevada Operations Office of the U.S. Department of Energy, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [244201]
La Camera, Westenburg, and Locke 1996	La Camera, R. J., C. L. Westenburg, and G. L. Locke, 1996, *Selected Ground-Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, Through December 1995,* OFR-96-553, in cooperation with the Nevada Operations Office of the U.S. Department of Energy, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [MOL.19990513.0041]
Las Vegas Review-Journal 1998	*Las Vegas Review-Journal,* 1998, "Sizzling heat near all-time high predicted for coming five days," July 16, Las Vegas, Nevada. [244132]
Las Vegas Sun 1999	*Las Vegas Sun,* 1999, "Las Vegas Hotel and Casino Construction," http://www.vegasresorts.com/new/hotels/alladin.html, hardrock.html, paradise.html, paris.html, summerlin.html, venetian.html, May 14, Las Vegas Sun, Inc., Las Vegas, Nevada. [244052]
LeFever 1998a	LeFever, C., 1998a, "OCRWM Project Rail Route Evaluation – Total Estimated Water Usage," Data Request #004, Revision 01 – "Rail Construction Water Needs," internal electronic communication to B. Fogdall, August 18, Science Applications International Corporation, Las Vegas, Nevada. [MOL.19990322.0266]

LeFever 1998b	LeFever, C., 1998b, "RTEF Data Request #045," internal electronic communication to B. Fogdall, August 17, Science Applications International Corporation, Las Vegas, Nevada. [MOL.19990616.0158]
Lehman and Brown 1996	Lehman, L. L., and T. P. Brown, 1996, "Nuclear Waste Technical Review Board Winter Board Meeting January 20-21, 1997 – Summary of State of Nevada-Funded Studies of the Saturated Zone at Yucca Mountain, Nevada Performed by L. Lehman," paper presented at the Nuclear Waste Technical Review Board public meeting, Amargosa Valley, Nevada, L. Lehman & Associates, Inc., Burnsville, Minnesota. [231894]
Lemons and Malone 1989	Lemons, J. and C. R., Malone, 1989, "Siting America's Geologic Repository for High-Level Nuclear Waste: Implications for Environmental Policy," *Environmental Management,* 13:435-441. [241782]
Levy et al. 1997	Levy, S. S., D. S. Sweetkind, J. Fabryka-Martin, P. Dixon, J. Roach, L. Wolfsberg, D. Elmore, and P. Sharma, 1997, unpublished, *Investigations of Structural Controls and Mineralogic Associations of Chlorine-36 Fast Pathways in the ESF,* LA-EES-1-TIP-97-004, YMP Milestone Report SP2301M4, Los Alamos National Laboratory, Los Alamos, New Mexico. [MOL.19971119.0044]
Luckey et al. 1996	Luckey, R. R., P. Tucci, C. C. Faunt, E. M. Ervin, W. C. Steinkampf, F. A. D'Agnese, and G. L. Patterson, 1996, *Status of Understanding of the Saturated-Zone Ground-Water Flow System at Yucca Mountain, Nevada, As of 1995,* USGS/WRIR96-4077, U.S. Geological Survey in cooperation with U.S. Department of Energy, Denver, Colorado. [227084]
Luna, Neuhauser, and Vigil 1999	Luna, R. E., K. S. Neuhauser, and M. G. Vigil, 1999, *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments to a Yucca Mountain High Level Waste Repository,* Sandia National Laboratories, Albuquerque, New Mexico. [MOL.19990609.0160]
LVCVA 1999	LVCVA (Las Vegas Convention and Visitors Authority), 1999, "Clark County Visitor Statistics 1970-1998," http://www.lasvegas24hours.com/general/gen_vstat.html, April 30, Las Vegas, Nevada. [244070]
Malmberg and Eakin 1962	Malmberg, G. T., and T. E. Eakin, 1962, *Ground-Water Appraisal of Sarcobatus Flat and Oasis Valley, Nye and Esmeralda Counties, Nevada,* Ground-Water Resources – Reconnaissance Series, Report 10, Nevada Department of Conservation and Natural Resources in cooperation with the U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [208666]
Malone 1989	Malone, C. R., 1989, "Environmental Review and Regulation for Siting a Nuclear Waste Repository at Yucca Mountain, Nevada," *Environmental Impact Assessment Review,* Number 9, pp. 77-95, Plenum Press, New York, New York. [241459]

Malone 1995	Malone, C. R., 1995, "Ecology, Ethics, and Professional Environmental Practice: The Yucca Mountain Nevada Project as a Case Study," *Environmental Professional,* 17:271-284. [240317]
MARAD 1998	MARAD (U.S. Maritime Administration), 1998, "Waterborne Commerce at U.S. Ports," http://marad.dot.gov/arpt2s1b.htm, March 24, Washington, D.C. [243778]
McCauley 1997	McCauley, J., 1997, "The Challenge of Supplying Power In Booming Pahrump Valley," *Pahrump Valley Magazine,* Eighth Annual Edition, pp. 54-55, Pahrump Valley Chamber of Commerce, Pahrump, Nevada. [240471]
McKenzie 1998	McKenzie, D., 1998, "Erionite Encounters in Expanded Layouts," electronic mail to D. Walker (Jason Technologies Corporation), December 21, Morrison Knudsen Corporation, Las Vegas, Nevada. [MOL.19990511.0294]
Meyers 1998	Meyers, A., 1998, "Repository EIS Contact Report to Gather Employment Information for the Bullfrog Mine," personal communication with T. Cauliflower (Science Applications International Corporation), March 20, Human Resources Manager, Barrick Gold Corporation, Nye County, Nevada. [MOL.19990429.0213]
MIMS 1999	MIMS (Manifest Information Management Systems), 1999, "Annual Volume and Activity Summary," http://mims.inel.gov/web/owa/vol.report, May 23, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho. [244119]
Mishima 1998	Mishima, J., 1998, "Potential Airborne Release of Particulate Materials During Degradation of Commercial Spent Nuclear Fuel," personal communication with E. Rollins (Tetra Tech NUS, Inc.), August 20, Jason Technologies Corporation, Las Vegas, Nevada. [241186]
Napier et al. 1997	Napier, B. A., D. L. Strenge, R. A. Peloquin, J. V. Ramsdell, and P. D. Rittmann, 1997, *RSICC Computer Code Collection, GENII 1.485, Environmental Radiation Dosimetry Software System,* CCC-601, PNL-6584, Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Hanford, Washington. [206898]
National Research Council 1990	National Research Council, 1990, *Rethinking High-Level Radioactive Waste Disposal, A Position Statement of the Board on Radioactive Waste Management,* Commission on Geosciences, Environment, and Resources, National Academy Press, Washington, D.C. [205153]
National Research Council 1992	National Research Council, 1992, *Groundwater at Yucca Mountain: How High Can It Rise?,* National Academy Press, Washington, D.C. [204931]
National Research Council 1995	National Research Council, 1995, *Technical Bases for Yucca Mountain Standards,* Committee on Technical Bases for Yucca Mountain Standards, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources, National Academy Press, Washington, D.C. [217588]

National Research Council 1996	National Research Council, 1996, *Nuclear Wastes, Technologies for Separations and Transmutation,* Committee on Separations Technology and Transmutation Systems, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources, National Academy Press, Washington, D.C. [226607]
NCHS 1993	NCHS (National Center for Health Statistics), 1993, "Advance report of final mortality statistics, 1990," *Monthly Vital Statistics Report,* Volume 41, No. 7, Supplement, Public Health Service, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, Hyattsville, Maryland. [241180]
NCRP 1987	NCRP (National Council on Radiation Protection and Measurements), 1987, *Ionizing Radiation Exposure of the Population of the United States: Recommendations of the National Council on Radiation Protection and Measurements,* Report No. 93, Bethesda, Maryland. [229033]
NCRP 1993a	NCRP (National Council on Radiation Protection and Measurements), 1993a, *Limitation of Exposure to Ionizing Radiation: Recommendations of the National Council on Radiation Protection and Measurements,* Report No. 116, Bethesda, Maryland. [207090]
NCRP 1993b	NCRP (National Council on Radiation Protection and Measurements), 1993b, *Risk Estimates for Radiation Protection,* Report No. 115, Bethesda, Maryland. [232971]
NCRP 1996	NCRP (National Council on Radiation Protection and Measurements), 1996, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground, Recommendations of the National Council on Radiation Protection and Measurements,* Report No. 123, Bethesda, Maryland. [225158, Volume 1; 234986, Volume 2]
NDCNR 1971	NDCNR (Nevada Department of Conservation and Natural Resources), 1971, *Water for Nevada Report No. 3 Water Planning Report,* State Engineer's Office, Division of Water Resources, Carson City, Nevada. [217668]
NDCNR 1996	NDCNR (Nevada Department of Conservation and Natural Resources), 1996, "Class II Air Quality Operating Permit," No. AP9611-0573, Bureau of Air Quality, Division of Environmental Protection, Carson City, Nevada. [MOL.19960812.0465]
NDCNR 1998	NDCNR (Nevada Department of Conservation and Natural Resources), 1998, "1997 Ground Water Pumpage Inventory," Southern Nevada Branch Office, Division of Water Resources, Las Vegas, Nevada. [243820]
NDCNR 1999	NDCNR (Nevada Department of Conservation and Natural Resources), 1999, *State of Nevada Bureau of Air Quality 1988-1997 Trends Report,* Bureau of Air Quality, Division of Environmental Protection, Carson City, Nevada. [243946]

NDE 1997	NDE (Nevada Department of Education), 1997, *Research Bulletin: Student Enrollment and Licensed Personnel Information,* Volume 38, p. 4 and p. 13, Carson City, Nevada. [241551, 241586]
NDETR 1999	NDETR (Nevada Department of Employment, Training, and Rehabilitation), 1999, "1997 Nevada Labor Force Summary Data," table at http://www.state.nv/detr/lmi/lfrc.htm, April 26, Carson City, Nevada. [242922]
NDOT 1997	NDOT (Nevada Department of Transportation), 1997, *1996 Annual Traffic Report,* Research Division, Nevada Department of Transportation in cooperation with the U.S. Department of Transportation Federal Highway Administration, Carson City, Nevada. [242973]
NDWP 1992	NDWP (Nevada Division of Water Planning), 1992, *Nevada Water Facts 1992,* Carson City, Nevada. [241353]
NDWP 1998	NDWP (Nevada Division of Water Planning), 1998, "Information on Maps of Perennial Yield Information," Carson City, Nevada. [244120]
NDWP 1999a	NDWP (Nevada Division of Water Planning), 1999a, "Nevada Water Facts, Surface and Ground-Water Quality," http://www.state.nv.us/cnr/ndwp/wat-fact/sgwq.htm, April 21, Carson City, Nevada. [244073]
NDWP 1999b	NDWP (Nevada Division of Water Planning), 1999b, "Nevada Hydrographic Regions/Basins," http://www.state.nv.us/cnr/ndwp/basins/hydro-nv.htm, April 21, Carson City, Nevada. [244047]
Neuhauser and Kanipe 1992	Neuhauser, K. S., and F. L. Kanipe, 1992, *Users Guide for RADTRAN 4, Volume 3,* SAND89-2370, Sandia National Laboratories, Albuquerque, New Mexico. [206629]
NHTSA 1998	NHTSA (National Highway and Traffic Safety Administration), 1998, *Traffic Safety Facts 1997: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System,* DOT HS 808 806, National Center for Statistics and Analysis, U.S. Department of Transportation, Washington, D.C. [243959]
NIH 1999	NIH (National Institutes of Health), 1999, "Cancer Rates and Risks," http://rex.nci.nih.gov/NCI_Pub_Interface/raterisk/rates38.html, January 27, National Cancer Institute, Bethesda, Maryland. [243844]
Nimz and Thompson 1992	Nimz, G. J., and J. L. Thompson, 1992, *Underground Radionuclide Migration at the Nevada Test Site,* DOE/NV--346, Information Products Section, Reynolds Electrical Engineering Co., Inc., Las Vegas, Nevada. [233802]
NLCB 1996	NLCB (Nevada Legislative Counsel Bureau), 1996, *Local Financial Reporting, Statewide Summary Report: Counties, Cities, School Districts; Revenues and Expenditures FY 1993-94 (Actual) -- FY 1996-97 (Budget),* Fiscal Analysis Division, Carson City, Nevada. [243144]
NNHP 1997	NNHP (Nevada Natural Heritage Program), 1997, *Element Occurrence Database; February 20, 1997,* Nevada Department of Conservation and Natural Resources, Carson City, Nevada. [DTN: MO9903YMP99EBF.000]

NPC 1997	NPC (Nevada Power Company), 1997, *Nevada Power Company 1997 Resource Plan, Executive Summary, Volume 1,* Las Vegas, Nevada. [243146]
NRC 1976	NRC (U.S. Nuclear Regulatory Commission), 1976, *Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors,* NUREG-0002, Office of Nuclear Material Safety and Safeguards, Washington, D.C. [243889]
NRC 1979	NRC (U.S. Nuclear Regulatory Commission), 1979, *Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel,* Volume 1, "Executive Summary and Text," NUREG-0575-V-1, Office of Nuclear Material Safety and Safeguards, Washington, D.C. [216325]
NRC 1991	NRC (U.S. Nuclear Regulatory Commission), 1991, *Environmental Assessment Related to Construction and Operation of the Calvert Cliffs Independent Spent Fuel Storage Installation,* Docket No. 72-8 (50-317, -318), Baltimore Gas and Electric Company, Office of Nuclear Material Safety and Safeguards, Washington, D.C. [241726]
NRC 1995	NRC (U.S. Nuclear Regulatory Commission), 1995, "Interim NRR Procedure for Environmental Reviews," Office of Nuclear Materials Safety and Safeguards, Washington, D.C. [243843]
NRC 1996	NRC (U.S. Nuclear Regulatory Commission), 1996, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report,* NUREG-1437, Division of Regulatory Applications, Office of Nuclear Regulatory Research, Washington, D.C. [233963, Volume 1; 233962, Volume 2]
NRC 1997a	NRC (U.S. Nuclear Regulatory Commission), 1997a, *NRC Information Digest: 1997 Edition,* NUREG-1350, Volume 9, Washington, D.C. [231071]
NRC 1997b	NRC (U.S. Nuclear Regulatory Commission), 1997b, *Environmental Report, Private Fuel Storage Facility, Docket No. 72-22,* Revision 0, Private Fuel Storage L.L.C., Skull Valley Indian Reservation, Utah. [242887]
NRC 1998	NRC (U.S. Nuclear Regulatory Commission), 1998, "NRC Issues Certificate to General Atomics for Transportation Cask for Spent Nuclear Fuel," news release, October 30, Office of Public Affairs, Washington, D.C. [243426]
NRC 1999	NRC (U.S. Nuclear Regulatory Commission), 1999, *Draft supplement for the Generic Environmental Impact Statement for License Renewal of Nuclear Plants: Main Report, Section 6.3—Transportation, Table 9.1 Summary of findings on NEPA issues for license renewal of nuclear power plants,* NUREG-1437, Volume 1, Addendum 1, Division of Reactor Program Management, Office of Nuclear Reactor Regulation, Washington, D.C. [244062]
NSDO 1998	NSDO (Nevada State Demographer's Office), 1998, *Population Estimates (1997) and Forecasts (1998-2018),* University of Nevada-Reno, Reno, Nevada. [244497]

NSHD 1999 — NSHD (Nevada State Health Division), 1999, "Low-Level Waste Site Post-Closure Activities," http://www.state.nv.us/health/bhps/raddocs/lowste.htm, February 16, Bureau of Health Protection Services, State of Nevada, Carson City, Nevada. [243845]

NUTECH 1989 — NUTECH Engineers, Inc., 1989, *The Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel,* NUHOMS® - 24P (NUH-002), Revision 1A, San Jose, California. [243591]

NWPO 1997 — NWPO (Nuclear Waste Project Office), 1997, "Public Inquiry – Various Concerns," letter with Attachments 1 and 2 to W. Barnes (Yucca Mountain Project Office, Department of Energy), February 6, Carson City, Nevada. [MOL.19970718.0117, correspondence; MOL.19970718.0118, Attachment 1; MOL.19970718.0119, Attachment 2]

OECD 1997 — OECD (Organisation for Economic Co-Operation and Development), 1997, *Lessons Learnt From Ten Performance Assessment Studies,* No. 79979, Working Group on Integrated Performance Assessments of Deep Repositories, Nuclear Energy Agency, Paris, France. [243964]

OMB 1999 — OMB (Office of Management and Budget), 1999, "Definition of Poverty for Statistical Purposes, Statistical Policy Directive No. 14 [May 1978], http://www.census.gov/hhes/poverty/povmeas/ombdir14.html, May 4, Washington, D.C. [243151]

ORNL 1999 — ORNL (Oak Ridge National Laboratory), 1999, *Technical Appendix, Our Nation's Travel, 1995 NPTS Early Results Report,* Center for Transportation Analysis, Oak Ridge, Tennessee. [244043]

Orthen 1999 — Orthen, R. F., Jr., 1999, *Health, Safety, and Environmental Impacts During Controlled Long-Term Storage of Spent Nuclear Fuel And High-Level Radioactive Waste in the United States,* Tetra Tech NUS, Inc., Aiken, South Carolina. [MOL.19990608.0047]

Oversby 1987 — Oversby, V. M., 1987, "Spent fuel as a waste form – data needs to allow long term performance assessment under repository disposal conditions," *Scientific Basis for Nuclear Waste Management: symposium held December 1-4, 1986,* J. K. Bates and W. B. Seefeldt, editors, Volume 84, pp. 87-101, Materials Research Society, Pittsburgh, Pennsylvania. [243874]

Peters 1999 — Peters, M., 1999, "Observation of Water/Moisture in the ESF," electronic communication with K. Davis (Jason Technologies Corporation), January 6, Los Alamos National Laboratory, Las Vegas, Nevada. [MOL.19990513.0043]

PGE 1996 — PGE (Portland General Electric), 1996, *Trojan Independent Spent Fuel Storage Installation Safety Analysis Report,* Oregon. [243815]

Poe 1998a — Poe, W. L., Jr., 1998a, *Final Long-Term Degradation of Concrete Facilities Presently Used for Storage of Spent Nuclear Fuel and High-Level Waste,* Revision 1, Tetra Tech NUS, Inc., Aiken, South Carolina. [244048]

Poe 1998b	Poe, W. L., Jr., 1998b, *Final Regional Binning for Continued Storage Of Spent Nuclear Fuel and High-Level Wastes,* Revision 1, Tetra Tech NUS, Inc., Aiken, South Carolina. [244049]
Poe 1999	Poe, W. L., Jr., 1999, *Long Term Environmental Analysis of Total Inventory of Spent Nuclear Fuel and High-Level Waste for No-Action Alternative of Yucca Mountain Environmental Impact Statement,* Tetra Tech NUS, Inc., Aiken, South Carolina. [MOL.19990513.0042]
Rautenstrauch and O'Farrell 1998	Rautenstrauch, K. R., and T. P. O'Farrell, 1998, "Relative Abundance of Desert Tortoises on the Nevada Test Site," *Southwestern Naturalist,* Volume 43, Number 3, pp. 407-411. [242257]
Rautenstrauch, Brown, and Goodwin 1994	Rautenstrauch, K. R., G. A. Brown, and R. G. Goodwin, 1994, *The Northern Boundary of the Desert Tortoise Range on the Nevada Test Site,* Report 11265-1103, EG&G Energy Measurements, Inc., Las Vegas, Nevada. [240498]
Raytheon 1994	Raytheon Services Nevada, 1994, *Draft White Paper Subject: High Speed Surface Transportation Between Las Vegas and the Nevada Test Site (NTS),* Draft, Las Vegas, Nevada. [MOL.19950721.0007]
Reel 1998	Reel, J., 1998, "Unemployment Rates," electronic transmission to R. Long (Tetra Tech NUS, Inc.), April 2, Research and Analysis Bureau, Nevada Department of Employment, Training and Rehabilitation, Las Vegas, Nevada. [244110]
REMI 1999	REMI (Regional Economic Models, Inc.), 1999, "Product Information and Pricing," http://www.remi.com/html/product_info.html, April 14, Amherst, Maryland. [243947]
Resource Concepts 1989	Resource Concepts, Inc., 1989, "Soil Survey of Yucca Mountain Study Area, Nye County, Nevada," Carson City, Nevada. [206227]
Rodefer et al. 1996	Rodefer, T. (editor), S. Selmi, J. Butler, and M. Naroll, 1996, *Nevada Statistical Abstract 1996,* Nevada Department of Administration, Carson City, Nevada. [243961]
Rollins 1998	Rollins, E. M., 1998, *Final Radiological Impacts for Scenario 1 at Commercial Nuclear Power Facilities,* Tetra Tech NUS, Inc., Aiken, South Carolina. [244050]
Ross 1998	Ross, S., 1998, "Cask Fleet Size for Mostly LWT Scenario," with attachment, internal electronic communication to K. House, Battelle Memorial Institute, Albuquerque, New Mexico. [MOL.19990511.0388]
Rothman 1984	Rothman, A. J., 1984, *Potential Corrosion and Degradation Mechanisms of Zircaloy Cladding on Spent Fuel in a Tuff Repository,* UCID20172, Lawrence Livermore National Laboratory, California University-Livermore, Livermore, California. [NNA.19870903.0039]
Rush 1970	Rush, F. E., 1970, *Regional Ground-Water Systems in the Nevada Test Site Area, Nye, Lincoln, and Clark Counties, Nevada,* Water Resources – Reconnaissance Series Report 54, Division of Water Resources, Department of Conservation and Natural Resources in cooperation with the U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [HQS.19880517.1834]

Saricks and Tompkins 1999	Saricks, C. L., and M. M. Tompkins, 1999, *State-Level Accident Rates of Surface Freight Transportation: A Re-Examination,* ESD/TM-150, Argonne National Laboratory, Argonne, Illinois. [243751]
Savage et al. 1994	Savage, J. C., M. Lisowski, W. K. Gross, N. E. King, and J. L. Svarc, 1994, "Strain Accumulation Near Yucca Mountain, Nevada, 1983-1993," *Journal of Geophysical Research,* Volume 99, Number B9, pp. 18,103-18,107, American Geophysical Union, Washington, D.C. [235681]
Savage, Svarc, and Prescott 1998	Savage, J. C., J. L. Svarc, and W. H. Prescott, 1998, "Strain Accumulation at Yucca Mountain, Nevada, 1983-1998," *EOS, Transactions, American Geophysical Union,* Volume 79, Number 45, page F203, American Geophysical Union, Washington, D.C. [243124]
Sawyer et al. 1994	Sawyer, D. A., R. J. Fleck, M. A. Lanphere, R. G. Warren, D. E. Broxton, and M. R. Hudson, 1994, "Episodic Caldera Volcanism in the Miocene Southwestern Nevada Volcanic Field: Revised Stratigraphic Framework, 40-Ar/39-Ar Geochronology, and Implications for Magmatism and Extension," *Geological Society of America - Bulletin, 106,* pp. 1,304-1,318, Geological Society of America, Boulder, Colorado. [222523]
Schneider et al. 1987	Schneider, K. J., W. A. Ross, R. I. Smith, P. M. Daling, R. B. Grinde, C. J. Hostick, R. W. Peterson, D. L. Stiles, S. A. Weakley, and J. R. Young, 1987, *Analysis of Radiation Doses from Operation of Postulated Commercial Spent Fuel Transportation Systems, Main Report,* DOE/CH/TPO-001, Pacific Northwest Laboratory, U.S. Department of Energy, Richland, Washington. [208877]
Scott and Bonk 1984	Scott, R. B., and J. Bonk, 1984, *Preliminary Geological Map of Yucca Mountain, Nye County, Nevada, with Geologic Sections,* OFR-84-494, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [HQS.19880517.1443]
Sherwood 1998	Sherwood, M., 1998, "Telephone Conversation to Nevada Ready Mix in Regards to Looking for Numbers on Concrete Not Cement," personal communication with M. Bauhaus (Science Applications International Corporation), August 7, Nevada Ready Mix, Las Vegas, Nevada. [MOL.19990511.0382]
Simonds et al. 1995	Simonds, F. W., J. W. Whitney, K. F. Fox, A. R. Ramelli, J. C. Yount, M. D. Carr, C. M. Menges, R. P. Dickerson, and R. B. Scott, 1995, *Map Showing Fault Activity in the Yucca Mountain Area, Nye County, Nevada,* Map I-2520, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [MOL.19980618.0033]
Smith, Daling, and Faletti 1992	Smith, R. I., P. M. Daling, and D. W. Faletti, 1992, *Analysis of Radiation Doses from Operation of Postulated Commercial Spent Fuel Transportation Systems, Analysis of a System Containing a Monitored Retrievable Storage Facility,* DOE-CH/TPO--001, Addendum 1, Pacific Northwest Laboratory, Richland, Washington. [HQX.19920604.0012]

SNWA 1997	SNWA (Southern Nevada Water Authority), 1997, "Groundwater Protection Bill Drafted," *Water Wise,* Winter, Las Vegas, Nevada. [240485]
SNWA 1999	SNWA (Southern Nevada Water Authority), 1999, "Water Resources Frequently Asked Questions," http://www.lvvwd.com/snwa/waters/resfaq.html, April 13, Las Vegas, Nevada. [243918]
Souleyrette, Sathisan and di Bartolo 1991	Souleyrette, Jr., R. R., S. K. Sathisan, and R. di Bartolo, 1991, *Yucca Mountain Transportation Routes: Preliminary Characterization and Risk Analysis, Volume I: Research Report,* UNLV/TRC/RR-91/02, Transportation Research Center, University of Nevada-Las Vegas, Las Vegas, Nevada. [210900]
Spotila et al. 1994	Spotila, J. R., L. C. Zimmerman, C. A. Binckley, J. S. Grumbles, D. C. Rostal, A. List, Jr., E. C. Beyer, K. M. Phillips, and S. J. Kemp, 1994, "Effects of Incubation Conditions on Sex Determination, Hatching Success, and Growth of Hatchling Desert Tortoises, *Gopherus agassizii," Herpetological Monographs,* Number 8, pp. 103-116. [242868]
Squires and Young 1984	Squires, R. R., and R. L. Young, 1984, *Flood Potential of Fortymile Wash and Its Principal Southwestern Tributaries, Nevada Test Site, Southern, Nevada,* WRI-834001, U.S. Geological Survey, U.S. Department of the Interior, Carson City, Nevada. [203214]
Stoffle 1987	Stoffle, R. W., 1987, *Native Americans and Nuclear Waste Storage at Yucca Mountain, Nevada: Potential Impacts of Site Characterization Activities,* Institute for Social Research, University of Michigan, Ann Arbor, Michigan. [MOL.19980610.0352]
Stoffle et al. 1989	Stoffle, R. W., M. J. Evans, D. B. Halmo, and W. E. Niles, 1989, *Native American Plant Resources in the Yucca Mountain Area, Nevada, Interim Report,* Institute for Social Research, University of Michigan, Ann Arbor, Michigan. [200466]
Stoffle et al. 1990	Stoffle, R. W., D. B. Halmo, J. E. Olmsted, and M. J. Evans, 1990, *Native American Cultural Resource Studies at Yucca Mountain, Nevada,* Institute for Social Research, University of Michigan, Ann Arbor, Michigan. [201417]
Stoffle, Evans, and Harshbarger 1989	Stoffle, R. W., M. J. Evans, and C. J. Harshbarger, 1989, *Native American Interpretation of Cultural Resources in the Area of Yucca Mountain, Nevada,* U.S. Department of Energy, Yucca Mountain Site Characterization Office, Las Vegas, Nevada. [NNA.19890406.0052]
Stoffle, Olmsted, and Evans 1990	Stoffle, R. W., J. E. Olmsted, and M. J. Evans, 1990, *Literature Review and Ethnohistory of Native American Occupancy and Use of the Yucca Mountain Region,* Institute for Social Research, University of Michigan, Ann Arbor, Michigan. [NNA.19900516.0216]
Striffler et al. 1996	Striffler, P., G. M. O'Brien, T. Oliver, and P. Burger, 1996, *Draft Perched Water Characteristics and Occurrences, Yucca Mountain, Nevada,* in cooperation with the U.S. Department of Energy, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [MOL.19980224.0105]

Sygitowicz 1998	Sygitowicz, L. S., 1998, "Annual Nevada Test Site (NTS) Solid Waste Disposal (SWD) Reports – 1997," letter to K. A. Hoar (Nevada Operations Office, U.S. Department of Energy), February 3, Bechtel Nevada, Las Vegas, Nevada. [MOL.19990511.0375]
Szymanski 1989	Szymanski, J. S., 1989, "Conceptual considerations of the Yucca Mountain groundwater system with special emphasis on the adequacy of this system to accommodate a high-level nuclear waste repository," Yucca Mountain Project Office, U.S. Department of Energy, Las Vegas, Nevada. [NNA.19890831.0152]
Tappen and Andrews 1990	Tappen, J. J., and W. B. Andrews, 1990, *Preliminary Rail Access Study,* DOE/YMP-89-16, Technical and Management Support Services Contractor, Yucca Mountain Project Office, Nevada Operations Office, U.S. Department of Energy, Las Vegas, Nevada. [MOL.19980817.0094]
Thiel 1997	Thiel (Thiel Engineering Consultants), 1997, *Data Assessment & Water Rights/Resource Analysis of: Hydrographic Region No. 14, Death Valley Basin,* Reno, Nevada. [MOL.19990617.0239]
Thomas, Hjalmarson, and Waltemeyer 1997	Thomas, B. E., H. W. Hjalmarson, and S. D. Waltemeyer, 1997, *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States,* USGS Water Supply Paper 2433, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [243122]
Thomas, Pendleton, and Cappannari 1986	Thomas, D. H., L. S. A. Pendleton, and S. C. Cappannari, 1986, "Western Shoshone," Volume 11, *Handbook of North American Indians,* pp. 262-283, W. C. Sturtevant, general editor, Smithsonian Institution, Washington, D.C. [243801]
Thomas, Welch, and Dettinger 1996	Thomas, J. M., A. H. Welch, and M. D. Dettinger, 1996, *Geochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent States: regional aquifer-system analysis,* Professional Paper 1409-C, U.S. Geological Survey, U.S. Department of the Interior, Denver, Colorado. [235070]
Thurman 1997	Thurman, K., 1997, internal personal communication with S. LeStrange, December 9, Science Applications International Corporation, Las Vegas, Nevada. [MOL.19990224.0384]
Timbisha Shoshone and DOI 1999	Timbisha Shoshone Tribe and DOI (U.S. Department of the Interior), 1999, *The Timbisha Shoshone Tribal Homeland: A Draft Secretarial Report to Congress to Establish a Permanent Tribal Land Base and Related Cooperative Activities,* Death Valley Junction, California. [244061]
Toblin 1998	Toblin, A. L., 1998, *Final Radionuclide Transport and Dose Commitment From Drinking Water from Continued Storage and Degradation of Spent Nuclear Fuel and High-Level Waste Materials Under Loss of Institutional Control,* Tetra Tech NUS, Inc., Gaithersburg, Maryland. [244116]
Treyz, Rickman, and Shao 1992	Treyz, G. I., D. S. Rickman, and G. Shao, 1992, "The REMI Economic-Demographic Forecasting and Simulation Model," *International Regional Science Review,* Volume 14, Number 3, pp. 221-253, Morgantown, West Virginia. [242687]

TRW 1993 — TRW (TRW Environmental Safety Systems Inc.), 1993, *Repository Subsurface Layout Options and ESF Interface,* B00000000-01717-5705-00009, Revision 00, Las Vegas, Nevada. [NNA.19940124.0036]

TRW 1994a — TRW (TRW Environmental Safety Systems Inc.), 1994a, *Socioeconomic Monitoring Program 1994, U.S. Department of Energy/Nevada Employee Survey Data Report – Executive Summary,* Las Vegas, Nevada. [MOL.19950518.0077]

TRW 1994b — TRW (TRW Environmental Safety Systems Inc.), 1994b, *Health and Safety Impacts Analysis for the Multi-Purpose Canister System and Alternatives,* A00000000-01717-0200-00006, Revision 2, Vienna, Virginia. [MOV.19950217.0043]

TRW 1995a — TRW (TRW Environmental Safety Systems Inc.), 1995a, *Nevada Potential Repository Preliminary Transportation Strategy, Study 1,* B00000000-01717-4600-00023, Revision 01, Las Vegas, Nevada. [MOL.19960729.0195]

TRW 1995b — TRW (TRW Environmental Safety Systems Inc.), 1995b, *Total System Performance Assessment – 1995, An Evaluation of the Potential Yucca Mountain Repository,* B00000000-01717-2200-00136, Revision 01, Las Vegas, Nevada. [MOL.19960724.0188]

TRW 1996 — TRW (TRW Environmental Safety Systems Inc.), 1996, *Nevada Potential Repository Preliminary Transportation Strategy, Study 2,* B00000000-01717-4600-00050, Revision 01, Las Vegas, Nevada. [MOL.19960724.0199, Volume 1; MOL.19960724.0200, Volume 2]

TRW 1997a — TRW (TRW Environmental Safety Systems Inc.), 1997a, *Engineering Design Climatology and Regional Meteorological Conditions Report,* B00000000-01717-5707-00066, Revision 00, Las Vegas, Nevada. [MOL.19980304.0028]

TRW 1997b — TRW (TRW Environmental Safety Systems Inc.), 1997b, *The Distribution and Relative Abundance of Desert Tortoises at Yucca Mountain,* B00000000-01717-5705-00033, Las Vegas, Nevada. [MOL.19980123.0643]

TRW 1997c — TRW (TRW Environmental Safety Systems Inc.), 1997c, *Overall Development and Emplacement Ventilation Systems,* BCA000000-01717-0200-00015, Revision 00, Las Vegas, Nevada. [MOL.19980123.0661]

TRW 1997d — TRW (TRW Environmental Safety Systems Inc.), 1997d, *Retrievability Strategy Report,* B00000000-01717-5705-00061, Revision 00, Las Vegas, Nevada. [MOL.19970813.0110]

TRW 1998a — TRW (TRW Environmental Safety Systems Inc.), 1998a, *Yucca Mountain Site Description,* B00000000-01717-5700-00019, Revision 00, Las Vegas, Nevada. [MOL.19980729.0047, Book 1, Section 1; MOL.19980729.0048, Book 1, Section 2; MOL.19980729.0049, Book 1, Section 3; MOL.19980729.0050, Book 2, Section 4; MOL.19980729.0051, Book 2, Section 5; MOL.19980729.0052, Book 3, Section 6; MOL.19980729.0053, Book 3, Section 7]

TRW 1998b — TRW (TRW Environmental Safety Systems Inc.), 1998b, *Radioactivity in FY 1997 Groundwater Samples from Wells and Springs Near Yucca Mountain,* Revision 00, Las Vegas, Nevada. [MOL.19990218.0213]

TRW 1998c — TRW (TRW Environmental Safety Systems Inc.), 1998c, *Classification and Map of Vegetation at Yucca and Little Skull Mountains,* B00000000-01717-5705-00083, Revision 00B, Las Vegas, Nevada. [MOL.19990211.0519]

TRW 1998d — TRW (TRW Environmental Safety Systems Inc.), 1998d, *Yucca Mountain Site Characterization Project: Socioeconomic Monitoring Program Quarterly Employment Data Report, October 1997 Through December 1997,* Las Vegas, Nevada. [MOL.19980428.0243]

TRW 1998e — TRW (TRW Environmental Safety Systems Inc.), 1998e, *Off-site Utilities Preliminary Assessment,* B00000000-01717-5705-00091, Revision 00, Las Vegas, Nevada. [MOL.19980519.0235]

TRW 1998f — TRW (TRW Environmental Safety Systems Inc.), 1998f, *Repository Surface Design Site Layout Analysis,* BCB000000-01717-0200-00007, Revision 02, Las Vegas, Nevada. [MOL.19980410.0136]

TRW 1998g — TRW (TRW Environmental Safety Systems Inc.), 1998g, *Site Gas/Liquid Systems Technical Report,* BCBC00000-01717-5705-00001, Revision 00, Las Vegas, Nevada. [MOL.19980501.0178]

TRW 1998h — TRW (TRW Environmental Safety Systems Inc.), 1998h, *Efficacy of Relocating Desert Tortoises for the Yucca Mountain Site Characterization Project,* B00000000-01717-5705-00032, Revision 00, Las Vegas, Nevada. [MOL.19981014.0309]

TRW 1998i — TRW (TRW Environmental Safety Systems Inc.), 1998i, *Monitored Geologic Repository Operations Staffing Report,* BC0000000-01717-5705-00021, Revision 00, Las Vegas, Nevada. [MOL.19981211.0036]

TRW 1998j — TRW (TRW Environmental Safety Systems Inc.), 1998j, *1998 Waste Acceptance, Storage, and Transportation Life Cycle Cost Report,* A10000000-01717-5708-00003, Revision 00, Vienna, Virginia. [MOV.19980814.0005]

TRW 1998k — TRW (TRW Environmental Safety Systems Inc.), 1998k, "Chapter 6: Waste Form Degradation, Radionuclide Mobilization and Transport through the Engineered Barrier System," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00006, Revision 01, Las Vegas, Nevada. [MOL.19981008.0006]

TRW 1998l — TRW (TRW Environmental Safety Systems Inc.), 1998l, *User Manual for the CRWMS Analysis and Logistics Visually Interactive Model, Version 1.0,* 30064-2003, Revision 00A, Systems Analysis and Integration Department, Vienna, Virginia. [MOL.19990608.0046]

TRW 1998m — TRW (TRW Environmental Safety Systems Inc.), 1998m, "Chapter 1: Introduction," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00001, Revision 01, Las Vegas, Nevada. [MOL.19981008.0001]

TRW 1998n — TRW (TRW Environmental Safety Systems Inc.), 1998n, "Chapter 2: Unsaturated Zone Hydrology Model," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00002, Revision 01, Las Vegas, Nevada. [MOL.19981008.0002]

TRW 1998o — TRW (TRW Environmental Safety Systems Inc.), 1998o, "Chapter 3: Thermal Hydrology," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00003, Revision 01, Las Vegas, Nevada. [MOL.19981008.0003]

TRW 1998p — TRW (TRW Environmental Safety Systems Inc.), 1998p, "Chapter 4: Near-Field Geochemical Environmental," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00004, Revision 01, Las Vegas, Nevada. [MOL.19981008.0004]

TRW 1998q — TRW (TRW Environmental Safety Systems Inc.), 1998q, "Chapter 5: Waste Package Degradation Modeling Abstraction," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00005, Revision 01, Las Vegas, Nevada. [MOL.19981008.0005]

TRW 1998r — TRW (TRW Environmental Safety Systems Inc.), 1998r, "Chapter 7: Unsaturated Zone Radionuclide Transport," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00007, Revision 01, Las Vegas, Nevada. [MOL.19981008.0007]

TRW 1998s — TRW (TRW Environmental Safety Systems Inc.), 1998s, "Chapter 8: Saturated Zone Flow Transport," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00008, Revision 01, Las Vegas, Nevada. [MOL.19981008.0008]

TRW 1998t — TRW (TRW Environmental Safety Systems Inc.), 1998t, "Chapter 9: Biosphere," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00009, Revision 01, Las Vegas, Nevada. [MOL.19981008.0009]

TRW 1998u — TRW (TRW Environmental Safety Systems Inc.), 1998u, "Chapter 10: Disruptive Events," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00010, Revision 01, Las Vegas, Nevada. [MOL.19981008.0010]

TRW 1998v — TRW (TRW Environmental Safety Systems Inc.), 1998v, "Chapter 11: Summary and Conclusion," *Total System Performance Assessment – Viability Assessment (TSPA-VA) Analyses Technical Basis Document,* B00000000-01717-4301-00011, Revision 01, Las Vegas, Nevada. [MOL.19981008.0011]

TRW 1999a — TRW (TRW Environmental Safety Systems Inc.), 1999a, *Repository Surface Design Engineering Files Report,* BCB000000-01717-5705-00009, Revision 03, Las Vegas, Nevada. [MOL.19990615.0238]

TRW 1999b — TRW (TRW Environmental Safety Systems Inc.), 1999b, *Engineering File – Subsurface Repository,* BCA000000-01717-5705-00005, Revision 02 with DCN1, Las Vegas, Nevada. [MOL.19990622.0202, document; MOL.19990621.0157, DCN1]

TRW 1999c — TRW (TRW Environmental Safety Systems Inc.), 1999c, *Waste Package Final Update to EIS Engineering File,* BBA000000-01717-5705-00019, Revision 01, Las Vegas, Nevada. [MOL.19990330.0530]

TRW 1999d — TRW (TRW Environmental Safety Systems Inc.), 1999d, *Nevada Transportation Engineering File,* Las Vegas, Nevada. [MOL.19990324.0257]

TRW 1999e — TRW (TRW Environmental Safety Systems Inc.), 1999e, *Environmental Impact Statement Cost Summary Report,* B00000000-01717-5700-00029, Revision 01, Las Vegas, Nevada. [MOL.19990622.0313]

TRW 1999f — TRW (TRW Environmental Safety Systems Inc.), 1999f, *Environmental Baseline File for Land Use,* B00000000-01717-5705-00115, Revision 00, Las Vegas, Nevada. [MOL.19990302.0178]

TRW 1999g — TRW (TRW Environmental Safety Systems Inc.), 1999g, *Environmental Baseline File for Meteorology and Air Quality,* B00000000-01717-5705-00126, Revision 00, Las Vegas, Nevada. [MOL.19990302.0186]

TRW 1999h — TRW (TRW Environmental Safety Systems Inc.), 1999h, *Geology/Hydrology Environmental Baseline File,* B00000000-01717-5700-00027, Revision 01, DCN1, Las Vegas, Nevada. [MOL.19990609.0156]

TRW 1999i — TRW (TRW Environmental Safety Systems Inc.), 1999i, *Environmental Baseline File for Water Resources,* B00000000-01717-5705-00118, Revision 01, Las Vegas, Nevada. [MOL.19990608.0036]

TRW 1999j — TRW (TRW Environmental Safety Systems Inc.), 1999j, *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services,* B00000000-01717-5705-00124, Revision 00, Las Vegas, Nevada. [MOL.19990302.0182]

TRW 1999k — TRW (TRW Environmental Safety Systems Inc.), 1999k, *Environmental Baseline File for Biological Resources,* B00000000-01717-5700-00009, Revision 00, Las Vegas, Nevada. [MOL.19990302.0181; MOL.19990330.0560, map attachments)

TRW 1999l — TRW (TRW Environmental Safety Systems Inc.), 1999l, *Environmental Baseline File for Soils,* B00000000-01717-5700-00007, Revision 00, Las Vegas, Nevada. [MOL.19990302.0180]

TRW 1999m	TRW (TRW Environmental Safety System Inc.), 1999m, *Environmental Baseline File for Archaeological Resources,* B00000000-01717-5705-00122, Revision 00, Las Vegas, Nevada. [MOL.19990302.0187]
TRW 1999n	TRW (TRW Environmental Safety Systems Inc.), 1999n, *Yucca Mountain Site Characterization Project Environmental Baseline File for Socioeconomics,* B00000000-01717-5705-00125, Revision 01, Las Vegas, Nevada. [MOL.19990608.0037]
TRW 1999o	TRW (TRW Environmental Safety Systems Inc.), 1999o, *Environmental Baseline File for Human Health,* B00000000-01717-5705-00114, Revision 01, Las Vegas, Nevada. [MOL.19990608.0035]
TRW 1999p	TRW (TRW Environmental Safety Systems Inc.), 1999p, *Environmental Baseline File: Aesthetics,* B00000000-01717-5705-00082, Revision 00, Las Vegas, Nevada. [MOL.19990302.0179]
TRW 1999q	TRW (TRW Environmental Safety Systems Inc.), 1999q, *Environmental Baseline File for Environmental Justice,* B00000000-01717-5705-00123, Revision 01, Las Vegas, Nevada. [MOL.19990608.0038]
TRW 1999r	TRW (TRW Environmental Safety Systems Inc.), 1999r, *Impact of Radioactive Waste Heat on Soil Temperatures,* BA0000000-01717-5700-00030, Revision 0, Las Vegas, Nevada. [MOL.19990309.0403]
TRW 1999s	TRW (TRW Environmental Safety Systems Inc.), 1999s, *Final Report: Plant and Soil Related Processes Along a Natural Thermal Gradient at Yucca Mountain, Nevada,* B00000000-01717-5705-00109, Revision 00, Las Vegas, Nevada. [MOL.19990513.0037]
TRW 1999t	TRW (TRW Environmental Safety Systems Inc.), 1999t, *Safety and Health Plan,* B00000000-01717-4600-00016, Revision 3, Management and Operating Contractor, Las Vegas, Nevada. [MOL.19990513.0069]
TRW 1999u	TRW (TRW Environmental Safety Systems Inc.), 1999u, *Environmental Baseline File for National Transportation, with Data Files,* B00000000-01717-5705-00116, Revision 01, Las Vegas, Nevada. [MOL.19990608.0033]
Turnipseed 1992	Turnipseed, R. M., 1992, "Transmittal of Official Ruling in matter of Application 52338 – Forty-mile Canyon-Jackass Flats Groundwater Basin, Nye County, NV," R. Michael Turnipseed, P. E, State Engineer, March 2, Office of the State Engineer of the State of Nevada, Carson City, Nevada. [HQX.19930511.0006]
United States v. Dann 1985	United States v. Dann, 1985, 470 U.S. 39 (1985), United States Supreme Court, Washington, D.C. [243427]
USAF 1999	USAF (U.S. Air Force), 1999, *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement,* Air Combat Command, U.S. Department of the Air Force, U. S. Department of Defense, Nellis Air Force Base, Nevada. [243264]

USDE 1999 — USDE (U.S. Department of Education), 1999, "Digest of Education Statistics 1997; Table 64, Public and private elementary and secondary teachers and public-teacher ratios by level: Fall 1955 to Fall 1997," http://nces.ed.gov/pubs/digest97/d97+064.html, May 30, National Center for Education Statistics, Washington, D.C. [244008]

USGS 1993 — USGS (U.S. Geological Survey), 1993, *What is Ground Water?,* OFR-93-643, Water Fact Sheet, U.S. Department of the Interior, Washington, D.C. [243570]

USGS 1998 — USGS (U.S. Geological Survey), 1998, *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada, Final Report,* U.S. Department of the Interior, Oakland, California. [MOL.19980619.0640]

USN 1984 — USN (U.S. Navy), 1984, *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Naval Submarine Reactor Plants,* PB90-193855, U.S. Department of the Navy in cooperation with the U.S. Department of Energy, Washington, D.C. [242986]

USN 1996a — USN (U.S. Navy), 1996a, *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel,* DOE/EIS-0251, in cooperation with the U.S. Department of Energy, Naval Nuclear Propulsion Program, U.S. Department of the Navy, U.S. Department of Defense, Arlington, Virginia. [227671]

USN 1996b — USN (U.S. Navy), 1996b, *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class, and Los Angeles Class Naval Reactor Plants,* U.S. Department of Defense, Bremerton, Washington. [242987]

USN 1997a — USN (U.S. Navy), 1997a, *Record of Decision for a Dry Storage Container System for the Management of Naval Spent Nuclear Fuel,* Naval Sea Systems Command, U.S. Department of the Navy, U.S. Department of Defense, Arlington, Virginia. [244223]

USN 1997b — USN (U.S. Navy), 1997b, *Second Record of Decision for a Dry Storage Container System for the Management of Naval Spent Nuclear Fuel,* Naval Sea Systems Command, U.S. Department of the Navy, U.S. Department of Defense, Arlington, Virginia. [244225]

USN 1998 — USN (U.S. Navy), 1998, *Final Environmental Impact Statement (FEIS) for the Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station (NAS) Fallon, Nevada,* U.S. Department of the Navy in cooperation with the Bureau of Land Management, U.S. Department of the Interior, Naval Air Station Fallon, Fallon, Nevada. [243879]

Utah State University 1996 — Utah State University, 1996, *Nevada GAP Analysis Project, Geographic Information System Coverage,* Utah Cooperative Fish and Wildlife Research Unit, Logan, Utah. [DTN: MO9901COV97208.000]

Waddell 1982	Waddell, R. K., 1982, *Two-Dimensional, Steady-State Model of Ground-Water Flow, Nevada Test Site and Vicinity, Nevada-California,* WRI-82-4085, U.S. Geological Survey, U.S. Department of the Interior in cooperation with the U.S. Department of Energy, Denver, Colorado. [203212]
Walker and Eakin 1963	Walker, G. E., and T. E. Eakin, 1963, *Ground-Water Resources – Reconnaissance Series Report 14, Geology and Ground Water of Amargosa Desert, Nevada-California,* in cooperation with the U.S. Geological Survey, U.S. Department of the Interior, Nevada Department of Conservation and Natural Resources, Carson City, Nevada. [208665]
Weiss, Noble, and Larson 1996	Weiss, S. I., D. C. Noble, and L. T. Larson, 1996, "Hydrothermal Origin and Significance of Pyrite in Ash-Flow Tuffs at Yucca Mountain, Nevada," *Economic Geology,* Volume 90, pp. 2,081-2,090, Economic Geology Publishing Co., El Paso, Texas. [234950]
Wernicke et al. 1998	Wernicke, B., J. L. Davis, R. A. Bennett, P. Elósegui, M. J. Abolins, R. J. Brady, M. A. House, N. A. Niemi, and J. K. Snow, 1998, "Anomalous Strain Accumulation in the Yucca Mountain Area, Nevada," *Science,* Volume 279, March 27, pp. 2096-2100. [235956]
Western Shoshone v. United States 1997	United States District Court, District of Nevada, Western Shoshone National Council et al. v. United States of America et al., 1997, "Plaintiffs' Opposition to Defendants' Motion to Dismiss," No.: CV-S-97-327-HDM (RLH), District of Nevada, United States District Court (downloaded from http://www.nativeweb.org/pages/legal/shoshone/dismiss_opp.htm, March 11, 1999). [243975]
Westrich 1982	Westrich, H. R., 1982, "The Solubility of LWR Core Debris in Sacrificial Floor Material," *Journal of Nuclear Materials,* Volume 110, pp. 324-332, North Holland Publishing Company, Amsterdam, Netherlands. [234101]
Wilson et al. 1994	Wilson, M. L., J. H. Gauthier, R. W. Barnard, G. E. Barr, H. A. Dockery, E. Dunn, R. R. Eaton, D. C. Guerin, N. Lu, M. J. Martinez, R. Nilson, C. A. Rautman, T. H. Robey, B. Ross, E. E. Ryder, A. R. Schenker, S. A. Shannon, L. H. Skinner, W. G. Halsey, J. D. Gansemer, L. C. Lewis, A. D. Lamont, I. R. Triay, A. Meijer, and D. E. Morris, 1994, *Total-System Performance Assessment for Yucca Mountain – SNL Second Iteration (TSPA-1993), Volume 2,* Sandia National Laboratories, Albuquerque, New Mexico. [NNA.19940112.0123]
Winograd and Thordarson 1975	Winograd, I. J., and W. Thordarson, 1975, *Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site,* Professional Paper 712-C, U.S. Geological Survey, U.S. Department of the Interior, Washington, D.C. [NNA.19870406.0201]
Yuan et al. 1995	Yuan, Y. C., S. Y. Chen, B. M. Biwer, and D. J. LePoire, 1995, *RISKIND - A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel,* ANL/EAD-1, Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois. [241380]

Zocher 1998 — Zocher, M., 1998, "Telephone Log for Railroad Materials Availability," personal communication with G. Brennon (Pacific Northern Rail Contractors Corporation), July 1, Jason Technologies Corporation, Las Vegas, Nevada. [MOL.19990415.0152]

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Preparers, Contributors, and Reviewers

13. PREPARERS, CONTRIBUTORS, AND REVIEWERS

13.1 Preparers and Contributors

This chapter lists the individuals who filled primary roles in the preparation of this environmental impact statement (EIS). Wendy R. Dixon of the U.S. Department of Energy (DOE) Yucca Mountain Project Office directed the preparation of the EIS. Primary support and assistance to DOE was provided by the EIS Preparation Team, led by Ted B. Doerr of Jason Technologies Corporation; other members of the team included Tetra Tech NUS Inc., Battelle, Dade Moeller & Associates, and H&R Technical Associates, Inc. Judith A. Shipman coordinated the work of the Jason Technologies Corporation production team (Dalene Glanz, Laura Hall, Virginia Hutchins, and Robin Klein). Paulette Brown, Christina Caprio, Glenn Caprio, Angela Drum, Heidi Guyot, Cindy Langdale, Terresa Orme, and Dawn Siekerman provided administrative, scheduling, and recordkeeping support.

DOE provided direction to the EIS Preparation Team, which was responsible for developing the analytical methodology and alternatives, coordinating the work tasks, performing the impact analyses, and producing the document. DOE was responsible for data quality, the scope and content of the EIS, and issue resolution and direction.

In addition, the Management and Operating Contractor to the DOE Yucca Mountain Site Characterization Office (TRW Environmental Safety Systems Inc. and its subcontractors) assisted in the preparation of supporting documentation and information for the EIS, as did Sandia, Argonne, and Oak Ridge National Laboratories. These organizations worked closely with the EIS Preparation Team under DOE direction.

DOE independently evaluated all supporting information and documentation prepared by these organizations. Further, DOE retained the responsibility for determining the appropriateness and adequacy of incorporating any data, analyses, and results of other work performed by these organizations in the EIS. The EIS Preparation Team was responsible for integrating such work into the EIS.

As required by Federal regulations (40 CFR 1506.5c), Jason Technologies Corporation and its subcontractors have signed NEPA Disclosure Statements in relation to the work they performed on this EIS. These statements appear at the end of this chapter.

Name	Education	Experience	Responsibility
U.S. Department of Energy			
Wendy R. Dixon	Postgraduate studies, Geology and Environmental Science M.B.A., Business B.A., Sociology	20 years – management of nuclear-related projects; 13 years – regulatory compliance and field management; 5 years – safety and health	EIS Project Manager, NEPA Compliance Officer
Kenneth J. Skipper	B.S., Geology, 1984	18 years – geotechnical/ environmental project management; Federal civil works projects planning, construction, operations, and performance monitoring	Document Manager

Name	Education	Experience	Responsibility
M. Jozette Booth	B.S., Business Administration	18 years – transportation and policy analysis, communications and public participation, intergovernmental and Native American consultations	Technical lead for transportation and American Indian Programs
EIS Preparation Team			
Ted B. Doerr Jason Technologies Corporation	Ph.D., Wildlife and Fisheries Sciences, 1988 M.S., Range Science, 1980 B.S., Wildlife and Fisheries Sciences, 1977	19 years – NEPA implementation, ecology, environmental and ecological risk assessments, mitigation development, and regulatory compliance	Project Manager
Ernest C. Harr, Jr. Jason Technologies Corporation	B.S., Zoology/Chemistry, 1977	10 years – preparation of NEPA documents; acted as DOE EM Headquarters NEPA Compliance Officer; reviewed many DOE waste management NEPA documents.	Deputy Project Manager
Jeffrey L. Weiler Jason Technologies Corporation	M.S., Resource Economics/Environmental Management, 1974 B.A., Political Science, 1970	28 years – management of large interdisciplinary project teams; interagency coordination; stakeholder involvement; NEPA compliance	Document Manager
John O. Shipman Tetra Tech NUS Inc.	B.A., English Literature, 1966	32 years – NEPA documentation, technical writing and editing, publications management; 10 years – public participation	Document Production Manager; technical editor of Draft EIS
Jeffrey P. McCann Jason Technologies Corporation	B.S., Geological Sciences, 1980	19 years – geological analyst; 5 years – preparation of NEPA documentation	Records/Data Manager
Rosanne L. Aaberg Battelle - Pacific Northwest National Laboratories	B.S., Chemical Engineering, 1976	20 years – nuclear-related projects; 9 years – environmental health physics	Air quality
William J. Berry Jason Technologies Corporation	Ph.D., Entomology, 1988 M.S., Biology, 1983 B. S., Biology, 1981	10 years – NEPA documents, ecological risk assessments, and habitat management plans	Biological resources
Ralph E. Best Jason Technologies Corporation	M.B.A., 1981 M.S., Electrical Engineering, 1970 B.S., Engineering Physics, 1964	34 years – energy, transportation, and environmental technology	Lead analyst, transportation

Name	Education	Experience	Responsibility
William J. Craig Tetra Tech NUS Inc.	M.S., Planning, 1977 B. S., Forestry, 1972	20 years – environmental project management, nuclear fuel planning and analyses, natural resource management, and nuclear powerplant siting and relicensing	Land use; socioeconomics
David Crowl Jason Technologies Corporation	B.A., Computer Science, 1985	15 years – editing and publications production	Editor
Keith D. Davis, PE Jason Technologies Corporation	M.S., Civil and Environmental Engineering, 1976 B.S., Civil Engineering, 1973	21 years – civil and environmental engineering; waste management; facility permitting and closure; site investigations, feasibility studies, and remedial action planning; 5 years – NEPA documentation experience	Hydrology; soils
Peter R. Davis Jason Technologies Corporation	Oak Ridge School of Reactor Technology, 1962 B.S. Physics, 1961	36 years – nuclear reactor and nuclear facility safety analysis and risk assessment	Accidents
Amy S. Duda Battelle Memorial Institute	B.A., English, 1996	7 years – technical editing; 4 years – NEPA documentation	Editor
Paul W. Eslinger Battelle – Pacific Northwest National Laboratories	Ph.D., Statistics, 1983 M.A., Mathematics, 1978 B.S., Mathematics, 1976	16 years – environmental risk and human and ecological risk analysis	Long-term performance analysis
Daniel M. Evans Tetra Tech NUS Inc.	M.S., Planning, 1985 B.A., Political Science, 1976	17 years – socioeconomic impact analysis and NEPA document management	EIS strategic planning, socioeconomics
Christian J. Fosmire Battelle – Pacific Northwest National Laboratories	M.S., Meteorology, 1993 B.S., Meteorology, 1990	4 years – atmospheric diffusion modeling and risk assessment	Air quality
Mary N. Hoganson Tetra Tech NUS Inc.	M.S. Biology, 1989 B.S., Biology, 1984	13 years – waste management and waste minimization; 5 years – NEPA document preparation	Waste management and hazardous materials
Richard H. Holder Jason Technologies Corporation	M.B.A., Business Administration, 1986 M.S., Electrical Engineering, 1970 B.S., Electrical Engineering, 1966	32 years – team and line management for nuclear utility, industrial, and overseas projects	EIS strategic planning; Deputy Project Manager, October 1996 to May 1998

Name	Education	Experience	Responsibility
R. Kingsley House, P.E. Jason Technologies Corporation	M.S., Engineering Science/Nuclear Option, 1963 B.S., Mechanical Engineering, 1960	38 years – nuclear and non-nuclear facility design, construction, testing, and operation; hazards analysis, safety analysis, and environmental impact analysis	Utilities, energy, materials, and site services; disposal container and shipping cask manufacturing.
Tracy A. Ikenberry, CHP Dade Moeller & Associates	M.S., Radiology & Radiation Biology, 1982 B.A., Biology, 1979	16 years – environmental and occupational radiation protection; 5 years – NEPA document management and technical analysis.	Air quality; health and safety
James P. Jessen Jason Technologies Corporation	Graduate Studies, Environmental Engineering, 1991-92 M.S., Nuclear Engineering and Health Physics, 1989 B.S., Chemical and Nuclear Engineering, 1988	11 years – environmental and nuclear safety studies of DOE and commercial nuclear facilities	Lead analyst – affected environment, short-term impacts
Douglas E. Kennemore, Jr. Tetra Tech NUS Inc.	M.S., Biology, 1995 B.S., Biology, 1991	7 years – biological consulting and impact assessment	Aesthetics
Lawrence J. Kripps H&R Technical Associates, Inc.	M.S., Nuclear Engineering, 1972 B.S., Nuclear Engineering, 1971	25 years – environmental evaluations, safety analyses, and risk assessments of nuclear and non-nuclear facilities and operations	Lead analyst – Proposed Action, cumulative impacts
Robert A. Lechel Battelle Memorial Institute	B.S., Environmental Studies and Planning: Hazardous Materials Management, 1995	3 years – transportation risk assessment and NEPA document production	Transportation
David H. Lester Jason Technologies Corporation	Ph.D., Chemical Engineering, 1969 M.S., Chemical Engineering, 1966 B.Che., Chemical Engineering, 1964	26 years – hazardous and nuclear waste management; nuclear Safety Analysis Reports, hazards analysis of waste storage operations, risk assessment of low-level nuclear waste burial operations, groundwater contamination transport modeling, performance assessment of high-level nuclear waste systems, design of treatment systems, design and analysis of high-level waste packages, and soil remediation studies	Lead analyst, long-term performance

Name	Education	Experience	Responsibility
Robert D. Long Tetra Tech NUS Inc.	M.S., Demography, 1994 B.A., Sociology, 1993	5 years – economic analysis and research	Socioeconomics
Thomas McSweeney, Battelle Memorial Institute	Ph.D., Chemical Engineering, 1967 M.A., Mathematics, 1964 M.S., Chemical Engineering, 1961 B.S., Chemical Engineering, 1960	30 years – risk and safety analysis; 12 years – transportation risk analysis	Transportation
Aparajita S. Morrison Tetra Tech NUS Inc.	B.S. Health Physics, 1985	13 years – radiation protection, facility startup, instrumentation testing, development of radiological controls program, monitoring and assessments, and health and safety analysis	Cumulative impacts
Elizabeth A. Nañez Battelle Memorial Institute	B.S., Industrial Engineering, 1990	6 years – environmental engineering; 4 years – NEPA document preparation; 1 year – transportation risk assessment	Transportation
William E. Nichols Battelle – Pacific Northwest National Laboratories	M.S., Civil Engineering, 1990 B.S., Agricultural Engineering, 1987	9 years – subsurface flow and transport modeling and model development, environmental dispersion modeling and model development, probabilistic risk assessment, total systems modeling for geologic radioactive waste disposal evaluation, and NEPA documents	Long-term performance analysis
Paul R. Nickens Battelle – Pacific Northwest National Laboratories	Ph.D., Anthropology, 1977 M.A., Anthropology, 1974 B.A., Anthropology, 1969	25 years – cultural resource management and Native American consultation	Cultural resources
Richard F. Orthen, CHMM, Tetra Tech NUS Inc.	B.S., Chemistry, 1979	20 years – occupational and environmental health physics; regulatory compliance; 9 years – radioactive/hazardous materials management; NEPA analysis	Health and safety, cumulative impacts; No-Action Alternative

Name	Education	Experience	Responsibility
W. Kent Ostler Jason Technologies Corporation	Ph.D., Plant Ecology, 1979 M.S., Botany, 1976 B.S., Botany, 1974	20 years – plant ecology and arid land reclamation; identification of techniques to mitigate human impacts on biotic communities; surveys and research on endangered and threatened species; mitigation strategies for recovery of species	Biological resources
Karen K. Patterson Tetra Tech NUS, Inc.	M.A., Biology, 1977 B.A., Biology, 1973	25 years – technology and environmental sciences; 10 years – technical editor; 5 years – preparing NEPA documents	Technical editor, No-Action Alternative
Peter J. Pelto, PE Battelle – Pacific Northwest National Laboratories	M.S., Chemical Engineering, 1980 B.S., Chemical Engineering, 1971	20 years – safety analysis, risk analysis, and systems analysis of nuclear powerplants, nuclear fuel cycle facilities, and radioactive waste management facilities	No-Action Alternative
W. Lee Poe Tetra Tech NUS Inc.	M.S., Chemical Engineering, 1951 B.S., Chemistry, 1949	48 years – working with nuclear materials at Savannah River Site	No-Action Alternative
Ted M. Poston Battelle – Pacific Northwest National Laboratories	M.S., Fisheries B.A., Biology	16 years – noise analysis; 22 years – environmental research and toxicology	Noise
Randy F. Reddick Battelle Memorial Institute	M.S., Environmental Health Engineering, 1983 B.S., Civil Engineering, 1982	14 years – NEPA compliance, document preparation, and safety studies	Affected environment
Joseph W. Rivers, Jr. Jason Technologies Corporation	B.S., Mechanical Engineering, 1982	16 years – commercial and DOE nuclear projects; design, systems engineering, safety analysis, and regulatory compliance	Lead analyst – inventory
Eugene M. Rollins Dade Moeller & Associates	M.S.P.H., Health Physics, 1976 B.S., Nuclear Engineering, 1973	22 years – technical and management experience in health physics and risk assessments related to the nuclear fuel cycle	Lead analyst – No-Action Alternative
Steven B. Ross Battelle Memorial Institute	M.S., Nuclear Engineering, 1987 B.S., Nuclear Engineering, 1985	10 years – safety analysis, risk assessment, transportation, regulatory analysis, and fire risk assessment	Transportation

Name	Education	Experience	Responsibility
Judith A. Shipman Jason Technologies Corporation	A.A., General Studies, 1991	21 years – document production; 14 years NEPA document production	Production Coordinator; editor
Diane S. Sinkowski Tetra Tech NUS Inc.	M.E., Environmental Engineering Sciences, 1994 B.S., Nuclear Engineering Sciences, 1990	4 years – calculating environmental impacts and health physics investigations and evaluations	No-Action Alternative
Dennis Strenge Battelle-Pacific Northwest National Laboratories	M.S. Chemical Engineering, 1968 B.S., Chemical Engineering+	31 years – environment exposure analysis and Dosimetry for accidental and chronic releases of radionuclides and chemicals	Accidents
Lucinda Low Swartz Battelle Memorial Institute	J.D., 1979 B.A., Political Science and Administrative Studies, 1976	19 years – environmental law and regulation, specializing in NEPA compliance	Summary
Desiree Thalley Battelle Memorial Institute	B.A., Journalism, 1983	14 years – technical editing; 8 years – NEPA documentation	Editor
Alan L. Toblin Tetra Tech NUS Inc.	M.S., Chemical Engineering, 1970 B.E., Chemical Engineering, 1968	27 years – analyzing radiological and chemical contaminant transport in water resources.	No-Action Alternative
John E. von Reis Jason Technologies Corporation	J.D., 1969 B.A., English (Prelegal), 1966	28 years – energy, environmental, resource and regulatory issues	Lead analyst – purpose and need, regulatory requirements, environmental justice
Dee H. Walker Jason Technologies Corporation	Ph.D., Chemical Engineering, 1963 M.S., Chemical Engineering, 1962 Oak Ridge School of Reactor Technology, 1954 B.S., Chemical Engineering, 1953	45 years – nuclear engineering; 10 years – effects of radiological releases on humans and the environment	Health and safety; Project Manager, October 1996 – May 1998
Paul F. Wise, CEA CHMM Tetra Tech NUS Inc.	M.S., Biology, 1984 B.S., Biology, 1982	3 years – preparing NEPA documents; 15 years – environmental and water quality, waste management, and environmental audits	Cumulative impacts

13.2 Reviewers

The DOE Yucca Mountain Project Office incorporated input into the preparation of this EIS from a number of other DOE offices that reviewed the document while it was under development. These included the Offices of Environmental Management, Naval Reactors, Nuclear Energy, Materials

Disposition, the National Spent Fuel Program, and the National High-Level Waste Program. The DOE Yucca Mountain Site Characterization Office, Nevada Operations Office, Idaho National Engineering and Environmental Laboratory, Hanford Site, and Savannah River Site also participated in the reviews of this EIS. In addition, personnel on assignment to the Yucca Mountain Project Office from the U.S. Department of the Interior Bureau of Reclamation provided technical review and other support, as did personnel from the DOE Office of Civilian Radioactive Waste Management Technical Support Services Contractor (Booz-Allen & Hamilton and its subcontractors).

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows. (check either (a) or (b) and list financial or other interest if (b) is checked)

(a) ☑ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By:

[signature]
Signature

James S. Holm
Name (Printed)

Director of Contracts
Title

Jason Associates Corporation
Company

June 7, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5c, which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purposes of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows: (check either (a) or (b) and list financial or other interest if (b) is checked).

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(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified by:

Janet Mandel

Signature

Janet M. Mandel

Name (Printed)

Manager, Contract Operations

Title

Tetra Tech NUS, Inc.

Company

June 4, 1999

Date

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2.

3.

Certified By: [signature]

Signature

RALPH K. HENRICKS

Name (Printed)

CONTRACTING OFFICER

Title

BATTELLE MEMORIAL INSTITUTE
COLUMBUS OPERATIONS

Company

June 7, 1999

Date

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Certified By:

[signature]
Signature

Matthew P. Moeller
Name (Printed)

Vice President
Title

Dade Moeller & Assoc.
Company

June 4, 1999
Date

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Financial or Other Interest

1.

2.

3.

Certified By:

Laura A. Hof
Signature

Laura A. Hofman
Name (Printed)

Vice President
Title

H&R Technical Associates, Inc.
Company

June 4, 1999
Date

14

Glossary

14. GLOSSARY

(Note: A number of the terms in the Glossary emphasize their project-specific relationship to the Yucca Mountain Repository EIS. Words in *italics* refer to other words in the glossary.)

100-year flood
A flood event of such magnitude that it occurs, on average, every 100 years; this equates to a 1-percent chance of its occurring in a given year.

500-year flood
A flood event of such magnitude that it occurs, on average, every 500 years; this equates to a 0.2-percent chance of its occurring in a given year.

A-weighted decibel scale
See *decibel, A-weighted.*

accessible environment
(1) The atmosphere, land surfaces, and surface waters beyond a *controlled area* that humans or animals can contact. (2) The area surrounding a *nuclear waste* disposal site.

accident
An unplanned sequence of events that results in undesirable consequences. Examples in this EIS include an inadvertent release of *radioactive* or hazardous materials from their containers or *confinement* to the *environment*; vehicular accidents during the transportation of highly radioactive materials; and industrial accidents that could affect workers in the facilities.

acre-foot
The volume of water required to cover 1 acre to a depth of 1 foot (about 1,200 cubic meters or 330,000 gallons).

actinide
Any of a series of chemically similar, mostly synthetic, *radioactive* elements with *atomic numbers* ranging from actinium-89 through lawrencium-103.

active institutional control
Continued Federal control of the Yucca Mountain Repository site including access control, maintenance, monitoring, and surveillance of facilities and waste. See *institutional control.*

affected environment
For an EIS, a description of the existing *environment* (that is, site description) covering information that relates directly to the scope of the *Proposed Action*, the *No-Action Alternative*, and the *implementing alternatives* being analyzed; in other words, the information necessary to assess or understand the *impacts*. This description must contain enough detail to support the impact analysis. The information must highlight "environmentally sensitive resources," if present; these include floodplains and wetlands, *threatened* and *endangered species*, prime and unique agricultural lands, and property of historic, archaeological, or architectural significance.

air lock
A chamber or room in which air pressure can be regulated, usually between two regions of unequal pressure. The isolation air locks each consist of two *bulkheads* with doors that open and close in sequence.

air quality

A measure of the quantity of pollutants, measured individually, in the air.

ALARA

See *as low as reasonably achievable.*

alcove

A small excavation (room) off the main tunnel of a repository used for scientific study or for installing equipment.

alkali flat

A level area or plain in an *arid* or semiarid region encrusted with alkali salts that become concentrated by evaporation and poor drainage. *Cap.* (Alkali Flat): An example of such terrain, approximately 25 miles south of Amargosa Valley along the Amargosa River.

alluvial fan

A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream where it issues from a narrow mountain valley on a plain or broad valley.

alluvium

Sedimentary material deposited by flowing water.

alpha particle

A positively charged particle ejected spontaneously from the *nuclei* of some *radioactive* elements. It is identical to a helium nucleus and has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). See *ionizing radiation.*

alternative

One of two or more actions, processes, or propositions from which a *decisionmaker* will determine the course to be followed. The *National Environmental Policy Act*, as amended, states that in preparing an EIS, an agency "shall ... (s)tudy, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" [42 USC 4321, Title I, Section 102 (E)]. The regulations of the Council on Environmental Quality that implement the National Environmental Policy Act indicate that the alternatives section in an EIS is "the heart of the environmental impact statement" (40 CFR 1502.14), and include rules for presenting the alternatives, including no action, and their estimated impacts.

This EIS has two alternatives: the *Proposed Action* under which DOE would construct, operate and monitor, and eventually close a *monitored geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain, and the *No-Action Alternative* under which DOE would end *site characterization* activities at Yucca Mountain and continue to accumulate spent nuclear fuel and high-level radioactive waste at commercial storage sites and DOE facilities. The *Nuclear Waste Policy Act* states that this EIS does not have to discuss alternatives to geologic disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the Proposed Action. See *implementing alternative.*

DOE will base its decision on whether the repository program should proceed toward a site recommendation for Yucca Mountain in part on the Final EIS.

Amargosa Desert

A broad northwest-trending basin between the Yucca Mountain area on the north and the Death Valley area to the south.

Amargosa River

The main drainage system of the *Amargosa Desert.* The Amargosa River drainage basin originates in the Pahute Mesa-Timber Mountain area north of Yucca Mountain and includes the main tributary systems of *Beatty Wash* and *Fortymile Wash.* The river, which is frequently dry along much of its length, flows southeastward through the Amargosa Desert and ends in the internal drainage system of Death Valley. In southwestern Nevada, the river flows though the Amargosa Valley.

ambient

(1) Undisturbed, natural conditions such as ambient temperature caused by climate or natural *subsurface* thermal gradients. (2) Surrounding conditions.

ambient air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in the immediate proximity to emission sources.

ambient air quality standards

Standards established on a Federal or state level that define the limits for airborne concentrations of designated *criteria pollutants* [nitrogen dioxide, *sulfur dioxide*, *carbon monoxide*, *particulate matter* with aerodynamic diameters less than 10 microns (PM_{10}), *ozone*, and lead] to protect public health with an adequate margin of safety (primary standards) and to protect public welfare, including plant and animal life, visibility, and materials (secondary standards). See *criteria pollutants.*

analyzed land withdrawal area

See *land withdrawal area.*

aquifer

A *subsurface* saturated rock unit (formation, group of formations, or part of a formation) of sufficient *permeability* to transmit *groundwater* and yield usable quantities of water to wells and springs.

aquitard

A leaky confining bed that transmits water at a very slow rate to or from an adjacent *aquifer.*

areal mass loading

The amount of *heavy metal* (usually expressed in metric tons of uranium or equivalent) emplaced per unit area in the proposed repository.

arid

Very dry, lacking moisture. Lacking in vegetation.

as low as reasonably achievable

A process that applies a graded approach to reducing *dose* levels to workers and the public, and releases of *radioactive* materials to the *environment.* The goal of this process, often referred to as *ALARA,* is not merely to reduce doses, but to reduce them to levels that are as low are reasonable achievable.

assembly

See *fuel assembly*.

atmospheric dispersion

Movement of a *contaminant* as a result of the cumulative effect of the wind patterns and random motions of the air.

atomic mass

The mass of a neutral atom, based on a relative scale, usually expressed in atomic mass units. See *atomic weight*.

atomic number

The number of protons in an atom's nucleus.

atomic weight

The relative mass of an atom based on a scale in which a specific carbon atom (carbon-12) is assigned a mass value of 12. Also known as relative *atomic mass*.

backfill

(1) The general fill placed in excavated areas of an underground facility; backfill for the proposed repository would be *tuff*. (2) The material or process used to refill an excavation.

background radiation

Radiation from cosmic sources, naturally occurring *radioactive* materials such as granite, and global fallout from nuclear testing.

Bare Mountain

An upfaulted mountain block that bounds the west side of *Crater Flat*.

barrier

Any material, structure, or condition (as a thermal barrier) that prevents or substantially delays the movement of water or *radionuclides*. See *natural barrier*.

basalt

A dark gray to black, dense to fine-grained *igneous* rock.

baseline

Documentation of current conditions so that changes can be identified.

Beatty Wash

A tributary drainage to the *Amargosa River*; drains the west and north sides of the Yucca Mountain area.

berm

A mound or wall of earth.

beta particle

A negative or positive *electron* emitted from a *nucleus* during beta decay, which is a radioactive transformation of a nuclide in which the atomic number increases or decreases by 1 and the mass number remains unchanged. See *ionizing radiation*.

biosphere
The ecosystem of the Earth and the living *organisms* inhabiting it.

block-bounding fault
A high-angle, normal fault with relatively large displacement that bounds one or both sides of the fault-block mountains typical of the Basin and Range province.

boiling-water reactor (BWR)
A *nuclear reactor* that uses boiling water to produce steam to drive a turbine.

borehole
A hole made with a drill, auger, or other tool for exploring *strata* in search of minerals, supplying water for blasting, emplacing waste, proving the position of old workings or faults, or releasing accumulations of gas or water. Boreholes include core holes, dry-well-monitoring holes, waste emplacement holes, and test holes for geophysical or *groundwater* characterization.

borosilicate glass
High-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.

borrow areas
Areas outside the rail corridor where construction personnel could obtain materials to be used in the establishment of a stable platform (subgrade) for the rail track. Aggregate crushing operations could occur in these areas.

buffer cars
Railcars in front of or in back of those carrying *spent nuclear fuel* and *high-level radioactive waste* to provide additional distance to possibly occupied railcars or to railcars carrying hazardous materials other than *radioactive* materials. Federal regulations require the separation of a railcar carrying spent nuclear fuel and high-level radioactive waste from a locomotive, occupied caboose, carload of undeveloped film, or railcar carrying another class of hazardous material by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

bulkhead
A wall or embankment in a mine or tunnel that protects against earthslide, fire, water, or gas.

burnup
A measure of *nuclear reactor* fuel consumption expressed either as the percentage of fuel atoms that have undergone *fission* or as the amount of energy produced per unit weight of fuel.

caldera
An enlarged volcanic crater formed by explosion or collapse of the original crater.

cancer
A malignant tumor of potentially unlimited growth, capable of invading surrounding tissue or spreading to other parts of the body.

candidate species
Species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

canister
A thin-walled, unshielded metal container used as: (1) a pour mold in which molten vitrified *high-level radioactive waste* can solidify and cool; (2) the container in which DOE and electric utilities place intact *spent nuclear fuel*, loose rods, or nonfuel components for shipping or storage; or (3) in general, a container used to provide radionuclide *confinement*. Canisters are used in combination with specialized overpacks that provide structural support, shielding or confinement for storage, transportation, and *emplacement*; overpacks are sometimes referred to as *casks*.

capillary barrier
A contact in the *unsaturated zone* between a *geologic* unit containing relatively small-diameter openings and a unit containing relatively large-diameter openings across which water does not flow.

carbon monoxide
A colorless, odorless, poisonous gas produced by incomplete fossil-fuel combustion; one of the six pollutants for which there is a national *ambient air quality standard*.

carbon steel
A steel that is tough but malleable and contains a small percentage of carbon. The outer *barrier* of *waste packages* is composed of carbon steel.

carcinogen
An agent capable of producing or inducing *cancer*.

carcinogenic
Capable of producing or inducing *cancer*.

cask
(1) A heavily shielded container that meets applicable regulatory requirements used to ship *spent nuclear fuel* or *high-level radioactive waste*; (2) a heavily shielded container used by DOE and utilities for the *dry storage* of spent nuclear fuel; usable only for storage, not for transportation to or *emplacement* in a repository.

chain reaction
A process in which some of the *neutrons* released in one *fission* event cause other fissions.

characterization
Activities in the laboratory or the field undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository. These activities include borings, surface excavations, excavations of exploratory shafts, limited *subsurface* lateral excavations and borings, and *in situ* testing to evaluate the suitability of a candidate site for the location of a repository, but do not include preliminary borings and geophysical testing to assess if *site characterization* should be undertaken.

Civilian Radioactive Waste Management System

The organizational system of the DOE Office of Civilian Radioactive Waste Management; it is the composite of the sites and all facilities, systems, equipment, materials, information, activities, and personnel required to perform the activities necessary to manage *radioactive* waste *disposal*.

cladding

The metallic outer sheath of a fuel element generally made of stainless steel or a *zirconium alloy*. It is intended to isolate the fuel element from the external *environment*.

clastic

Describing a rock or sediment composed mainly of broken fragments of preexisting minerals or rocks that have been transported from their places of origin.

climate states

Representations of climate conditions. Three different climate states are used to represent changes in climate over the periods of interest: present-day dry climate, long-term-average climate (about twice the precipitation of dry climate), and superpluvial climate (about three times the precipitation of dry climate).

closure

See *repository phases*.

co-disposal

A packaging method for *disposal* of *radioactive* waste in which two types of waste, such as *commercial spent nuclear fuel* and defense *high-level radioactive waste*, are combined in *disposal containers*. Co-disposal takes advantage of otherwise unused space in disposal containers and is more cost-effective than other methods to limit the reactivity of individual *waste packages*.

collective dose

See *population dose*.

colloid

Small particles in the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in *groundwater* arise from clay minerals.

colluvium

Loose earth material that has accumulated at the base of a hill, through the action of gravity.

commercial spent nuclear fuel

Commercial nuclear fuel rods that have been removed from *reactor* use. See *spent nuclear fuel* and *DOE spent nuclear fuel*.

conceptual model

A set of *qualitative* assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model should be compatible with one another and fit the existing data within the context of the given purpose of the model.

confinement

As it pertains to *radioactivity*, the retention of *radioactive* material within some specified bounds. Confinement differs from containment in that there is no absolute physical *barrier* in the former.

construction

See *repository phases*.

construction/demolition debris

Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include materials such as soil, rock, masonry materials, and lumber.

construction support areas

Areas along the rail route that could be used as temporary residences for construction crews, material and equipment storage areas, and concrete production areas. Such camps probably would be for the construction of routes far from population centers.

contaminant

A substance that contaminates (pollutes) air, soil, or water. Also, a hazardous substance that does not occur naturally or that occurs at levels greater than those that occur naturally in the surrounding *environment*.

contaminant flux

Movement of a *contaminant* across a surface boundary per unit time (for example, *curies* per year; milligrams per year).

contamination

The intrusion of undesirable elements (unwanted physical, chemical, biological, or radiological substances, or matter that has an adverse effect) to air, water, or land.

controlled area

A surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers (6 miles) in any direction from the outer boundary of the underground facility, and the underlying *subsurface*, which area has been committed to use as a *geologic repository* and from which incompatible activities would be prohibited before and after *permanent closure*.

convection

(1) Thermally driven *groundwater* flow or a heat-transfer mechanism for a gas phase. The bulk motion of a flowing fluid (gas or liquid) in the presence of a gravitational field, caused by temperature differences that, in turn, cause different areas of the fluid to have different densities (for example, warmer is less dense). (2) One of the processes that moves solutes in *groundwater*.

corridor

A strip of land in Nevada that encompasses one of several possible routes through which DOE could build a rail line or truck route to transport *spent nuclear fuel*, *high-level radioactive waste*, and other material to and from the Yucca Mountain Repository site.

corrosion

The process of dissolving or wearing away gradually, especially by chemical action.

corrosion-allowance material

Disposal container material, such as *carbon steel*, that oxidizes at a predictable rate in a corrosive environment.

corrosion-resistant material

Disposal container material, such as Alloy 22, that oxidizes slowly in a corrosive environment.

Crater Flat

A north-trending, 6- to 11-kilometer (4- to 7-mile)-wide area west of Yucca Mountain; bounded by *Bare Mountain* on the west and Yucca Mountain on the east.

credible event/credible accident

An event or *accident* scenario that the design of the *geologic repository* must consider.

criteria pollutants

Six common pollutants (*ozone*, *carbon monoxide*, *particulates*, *sulfur dioxide*, lead, and nitrogen dioxide) known to be hazardous to human health and for which the U.S. Environmental Protection Agency sets National Ambient Air Quality Standards under the Clean Air Act. See *toxic air pollutants*.

critical group

With regard to annual *dose*, the *maximally exposed individuals*. A group of members of the public whose *exposure* is reasonably homogeneous and includes individuals receiving the highest dose. The individuals making up the critical group may change with changes in *source term* and *pathway*.

criticality

The condition in which nuclear fuel sustains a *chain reaction*. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle.

criticality control

Set of measures taken to maintain nuclear materials, including *spent nuclear fuel*, in a *subcritical* condition during storage, transportation, and *disposal*, so no self-sustaining nuclear *chain reaction* can occur. Subcriticality is maintained by loading spent nuclear fuel in specific configurations that meet requirements related to fuel age, enrichment, and reduction in nuclear fuel reactivity through *burnup*.

cross drift

An approximately 2,800-meter (9,200-foot)-long *drift* excavated to provide researchers new opportunities to study the geologic profile of the rock in the proposed repository area beneath Yucca Mountain. Researchers will conduct a new battery of tests in the cross drift as part of ongoing studies to determine if Yucca Mountain would be a suitable host for a deep *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste*. The cross drift begins inside the *Exploratory Studies Facility* approximately 2,000 meters (6,600 feet) from the northern entrance and cuts through the entire stratigraphic section of the potential Upper Block emplacement area.

cumulative impact

The *impact* on the *environment* that results from the incremental impact(s) of an action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

curie

A unit of *radioactivity* equal to 37 billion *disintegrations* per second.

decay (radioactive)

The process in which one radionuclide spontaneously transforms into one or more different radionuclides called decay products.

decibel (dB)

A standard unit for measuring sound-pressure levels based on a reference sound pressure of 0.0002 dyne per square centimeter. This is the smallest sound a human can hear.

decibel, A-weighted (dBA)

A measurement of sound approximating the sensitivity of the human ear and used to characterize the intensity or loudness of sound.

decisionmaker

The group or individual responsible for making a decision on constructing and operating a *monitored geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain.

decommissioning

The process of removing from service a facility in which nuclear materials are handled. It usually involves decontaminating the facility so that it may be dismantled or dedicated to other purposes.

decontamination

A process that removes, destroys, or neutralizes chemical, biological, or radiological contamination from a person, object, or area.

dedicated freight rail service

A train that handles only one commodity (in this case, *spent nuclear fuel* or *high-level radioactive waste*); this separate train with its own crew would limit switching between trains of the railcars carrying these materials.

defense in depth

A strategy based on a system of multiple, independent, and redundant *barriers*, designed to ensure that failure in any one barrier does not result in failure of the entire system.

deformation

A change in the shape and size of a body.

design alternative

A fundamentally different conceptual design for a repository, which could stand alone as the License Application repository design concept.

design-basis event

Naturally or humanly induced events that are reasonably likely to occur one or more times before permanent closure of the *geologic repository's* operations area; in addition, any other natural or human-induced event that is unlikely, but is sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety.

design enhancement

An engineered *barrier* system feature that DOE is considering for possible inclusion in the *Viability Assessment* design for the Yucca Mountain Repository. Design enhancements are not considered to be essential to the successful performance of the repository. The EIS analysis of the *Proposed Action* will not include design enhancements, but will identify them as possible means of *mitigation*. If a design enhancement is added to the reference design in time for inclusion in the EIS, it will be evaluated as part of the Proposed Action design.

design feature

A specific element or attribute of the repository for which postclosure (long-term) performance could be evaluated independently of a specific repository design alternative or other design features.

deterministic

A single calculation using only a single value for each of the model parameters. A deterministic system is governed by definite rules of system behavior leading to cause and effect relationships and predictability. Deterministic calculations do not account for *uncertainty* in the physical relationships or parameter values.

dip-slip fault

A fault in which the relative displacement is along the direction of dip of the fault plane. If the block above the fault has moved downward it is a *normal fault*; upward movement indicates a *reverse fault*.

direct impact

Effect that results solely from the construction or operation of a proposed action without intermediate steps or processes. Examples include habitat destruction, soil disturbance, air emissions, and water use.

disintegration

Any transformation of a *nucleus*, whether spontaneous or induced by *irradiation*, in which the nucleus emits one or more particles or *photons*.

disposable canister

A canister for *spent nuclear fuel* or *high-level radioactive waste* with specialized overpacks to enable storage, transportation, and *emplacement* in a repository.

disposal

The *emplacement* in a repository of *high-level radioactive waste*, *spent nuclear fuel*, or other highly *radioactive* material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the *isolation* of such waste from the *accessible environment*.

disposal container

The *barrier* or shell, spacing structures or baskets, integral shielding, and packing and other absorbent materials inside or immediately surrounding the container (that is, attached to its outer surface). The disposal container would contain *spent nuclear fuel* and *high-level radioactive waste*, but would exist only after the outer lid weld is complete and accepted. The disposal container would not include the waste form or the encasing containers or canisters (high-level radioactive waste canisters, *DOE spent nuclear fuel* canisters, disposable canisters of *commercial spent nuclear fuel*, etc.).

disproportionately high and adverse human health effects

Effects that occur when *impacts* to a *minority population* or *low-income population* from exposure to an environmental hazard significantly exceed the impacts to the general population and, where available, to an appropriate comparison group.

disproportionately high and adverse environmental impacts

An environmental *impact* that is unacceptable or above generally accepted norms; these would include economic impacts of the *Proposed Action*. A disproportionately high impact is one (or the risk of one) to a *low-income population* or *minority population* that significantly exceeds the impact to the general population. In assessing cultural and aesthetic impacts, agencies consider impacts that would have unique effects on geographically dislocated or dispersed low-income or minority populations.

disruptive event

An unexpected event which, in the case of the repository, includes *human intrusion*, volcanic activity, *seismic* activity, and nuclear *criticality*. Disruptive events have two possible effects; (1) direct release of *radioactivity* to the surface, or (2) alteration of the expected behavior of the system.

dissolution

Change from a solid to a liquid state. Dissolving a substance in a solvent.

DOE spent nuclear fuel

Radioactive waste created by defense activities that consists of over 250 different types of *spent nuclear fuel* and is expected to contribute 2,333 *metric tons of heavy metal* (*MTHM*) to the total repository. The major contributor to this waste form is the N-reactor fuel currently stored at the Hanford Site. This waste form also includes 65 MTHM of *naval spent nuclear fuel*.

dose

The amount of *radioactive* energy that passes the exchange boundaries of an *organism* (skin, mucous membrane, etc.) and is taken into living tissues. Dose arises from a combination of the energy imparted by the *radiation* and the absorption efficiency of the affected organism or tissues. It is expressed in terms of units of the radiation taken in, the body weight or mass impacted, and the time over which the dose occurs or the *impact* is measured.

dose equivalent

(1) The number (corrected for background) zero and above that is recorded as representing an individual's *dose* from external *radiation* sources or internally deposited *radioactive* materials; (2) the product of the absorbed dose in *rads* and a quality factor; (3) the product of the absorbed dose, the quality factor, and any other modifying factors. The dose equivalent quantity is used for comparing the biological effectiveness of different kinds of radiation (based on the quality of radiation and its spatial distribution in the body) on a common scale; it is expressed in *rem*.

drift
From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the *shaft(s)* to the *alcoves* and rooms. Includes excavations for *emplacement* (emplacement drifts) and access (access mains).

drip shield
A sheet of impermeable material placed above the *waste package* to prevent seeping water from directly contacting the waste packages.

dry storage
Storage of *spent nuclear fuel* without immersing the fuel in water for cooling or shielding; it involves the encapsulation of spent fuel in a steel cylinder that might be in a concrete or massive steel *cask* or structure.

dual-purpose canister
A containment vessel structure specifically designed to store and transport *commercial spent nuclear fuel*.

earthquake
A series of elastic waves in the crust of the Earth caused by abrupt movement easing strains built up along *geologic* faults or by volcanic action and resulting in movement of the Earth's surface.

electron
A stable elementary particle that is the negatively charged constituent of ordinary matter.

emplacement
The act of placing *waste packages* in prepared positions.

endangered species
A species that is in danger of extinction throughout all or a significant part of its range; a formal listing of the Fish and Wildlife Service under the Endangered Species Act.

Energy Policy Act of 1992
Legislation that amends the *Nuclear Waste Policy Act* by directing (1) the Environmental Protection Agency to set site-specific public health and safety radiation protection standards from Yucca Mountain, and (2) the Nuclear Regulatory Commission to modify its technical requirements and licensing criteria to be consistent with the Environmental Protection Agency site-specific standards.

engineered barrier system
The *waste packages* and the underground facility. These are the designed, or engineered, components of the disposal system and the waste package.

enhanced design alternative
A combination (or variation) of one or more design alternatives and design features.

environment
(1) Includes water, air, and land and all plants and humans and other animals living therein, and the interrelationship existing among these. (2) The sum of all external conditions affecting the life, development, and survival of an *organism*.

environmental impact statement (EIS)

A detailed written statement to support a decision to proceed with major Federal actions affecting the quality of the human *environment*. This is required by the *National Environmental Policy Act*. The EIS describes:

> "...the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposed action (although the Nuclear Waste Policy Act, as amended, precludes consideration of certain alternatives); the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

Preparation of an EIS requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments. A Final EIS for the Yucca Mountain site is scheduled for publication in Fiscal Year 2000.

environmental justice

The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no population of people should subject to disproportionate negative environmental *impacts* of pollution or environmental hazards.

environmental monitoring

The process of sampling and analyzing environmental media in and around a facility to (1) confirm compliance with performance objectives and (2) detect *contamination* entering the *environment* to facilitate timely remedial action.

equilibrium

The state of a chemical system in which the phases do not undergo any spontaneous change in properties or proportions with time; a dynamic balance.

erionite

A natural fibrous *zeolite* in the rocks at Yucca Mountain that is listed as a known human carcinogen by recognized international agencies such as the International Agency for Research on Cancer.

escort cars

Railcars in which escort personnel would travel on trains carrying *spent nuclear fuel* or *high-level radioactive waste*.

evapotranspiration

The combined processes of evaporation and plant *transpiration* that remove water from the soil and return it to the air.

Exploratory Studies Facility

An underground laboratory at Yucca Mountain that includes an 8-kilometer (5-mile) main loop (tunnel), a 3-kilometer (2-mile) *cross drift*, and a research *alcove* system constructed for performing underground studies during *site characterization*. The data collected will contribute toward determining the suitability of the Yucca Mountain site as a repository. Some or all of the facility could be incorporated into the proposed repository.

exposure (to radiation)

The incidence of *radiation* on living or inanimate material by accident or intent. Background exposure is the exposure to natural *ionizing radiation*. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

exposure pathway

The course a chemical or physical agent takes from the source to the exposed *organism*; describes a unique mechanism by which an individual or population can become exposed to chemical or physical agents at or originating from a release site. Each exposure pathway includes a source or a release from a source, an exposure point, and an exposure route.

far-field

The area of the geosphere and *biosphere* far enough away from the repository that, when numerically modeled, releases from the repository are represented as a homogeneous, single-source effect.

fault

A fracture in rock along which movement of one side relative to the other has occurred.

Fiscal Year

A 12-month period to which a jurisdiction's annual budget applies and at the end of which its financial position and the results of its operations are determined. For example, the Fiscal Year for Clark and Nye Counties, the Cities of Las Vegas and North Las Vegas, the Towns of Tonopah and Pahrump, and the Clark County and Nye County School Districts runs from July 1 through the following June 30; the Federal Fiscal Year runs from October 1 through the following September 30.

fission

The splitting of a *nucleus* into at least two other nuclei, resulting in the release of two or three *neutrons* and a relatively large amount of energy.

fission products

A complex mixture of radionuclides produced by the process of *fission* that includes *radioactive* and nonradioactive radionuclides as well as the decay products of the *radioactive decay* of these nuclides. This can result in more than 200 *isotopes*.

Fortymile Wash

A major tributary to the *Amargosa River*; drains *Jackass Flats* to the east of Yucca Mountain; usually dry along most of its length.

fracture

A general term for any break in a rock, whether or not it causes displacement, caused by mechanical failure from stress. Fractures include cracks, joints, and *faults*. Fractures can act as pathways for rapid *groundwater* movement.

fuel assembly

A number of fuel elements held together by structural materials, used in a *nuclear reactor*. Sometimes called a fuel bundle.

fugitive dust

Particulate matter composed of soil; can include emissions from haul roads, wind erosion of exposed soil surfaces, and other activities in which soil is removed or redistributed.

fugitive emissions

Emissions released directly into the *atmosphere* that could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

GENII

A *deterministic* computer software code that evaluates *dose* from the migration of radionuclides introduced into the *accessible environment*, or *biosphere*, that may eventually affect humans through ingestion, inhalation, or direct *radiation*. It is used to develop biosphere dose conversion factors.

gamma ray

The most penetrating type of radiant nuclear energy. It does not contain particles and can be stopped by dense materials such as concrete or lead. *See ionizing radiation.*

general freight rail service

Railroad line service that uses trains that move railcars, each of which might contain a different commodity. Railcars carrying *spent nuclear fuel* or *high-level radioactive waste* could be switched (in railyards or on sidings) successively from one general freight train to another as they traveled from the commercial and DOE locations to Nevada.

geologic

Of or related to a natural process acting as a dynamic physical force on the Earth (faulting, erosion, mountain building resulting in rock formations, etc.).

geologic repository

A system for disposing of *radioactive* waste in excavated *geologic* media, including surface and *subsurface* areas of operation, and the adjacent part of the geologic setting that provides *isolation* of the radioactive waste in the *controlled area.*

Great Basin

A subprovince of the Basin and Range province, generally characterized by north-trending mountain ranges and intervening basins, stretching from eastern Oregon to southern California.

Greater-Than-Class-C waste

Low-level nuclear waste generated by the commercial sector that exceeds U.S. Nuclear Regulatory Commission concentration limits for Class-C low-level waste, as specified in 10 CFR Part 61. DOE is responsible for disposing of this type of waste from its nondefense programs.

ground support

The system (rock bolt with wire mesh, steel cast, cast or precast concrete sections) used to line the main and emplacement *drifts* to minimize rock or earth falling into the drifts.

groundwater

Water contained in pores or fractures in either the *unsaturated zone* or *saturated zone* below ground level.

habitat

Area in which a plant or animal lives and reproduces.

half-life (radiological)

The time in which half the atoms of a *radioactive* substance decay to another nuclear form. Half-lives range from millionths of a second to billions of years depending on the stability of the nuclei.

hazardous chemical

As defined under the Occupational Safety and Health Act and the Community Right-to-Know Act, a chemical that is a physical or health hazard.

hazardous pollutant

Hazardous chemical that can cause serious health and environmental hazards, and listed on the Federal list of hazardous air pollutants (42 USC 7412). See *toxic air pollutants*.

hazardous waste

Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

heavy-haul truck

An overweight, overdimension vehicle that must have permits from state highway authorities to use public highways; a vehicle DOE would use on public highways to move *spent nuclear fuel* or *high-level radioactive waste shipping casks* designed for a railcar.

heavy metal

All uranium, plutonium, and thorium used in a manmade *nuclear reactor*.

high-efficiency particulate air filter

A filter with an efficiency of at least 99.95 percent that separates particles from an air exhaust stream before the air is released to the atmosphere.

high-level radioactive waste

(1) The highly *radioactive* material that resulted from the reprocessing of *spent nuclear fuel*, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains *fission* products in sufficient concentrations. (2) Other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent *isolation*.

Highway Route-Controlled Quantities of Radioactive Material

Thresholds for certain quantities of *radioactive* materials above which shipments are subject to specific routing controls that apply to the highway carrier. These thresholds are defined by U.S. Department of Transportation regulations (49 CFR Part 177). (49 CFR Part 397 Subpart D defines routing requirements.)

horizon

See *repository horizon*.

human intrusion

The inadvertent disturbance of a *disposal* system by the activities of humans that could result in release of *radioactive* waste. 40 CFR Part 191 Subpart B requires that *performance assessments* consider the possibility of human intrusion.

hydrogeology

A study that encompasses the interrelationships of *geologic* materials and processes involving water.

hydrographic area

A groundwater basin.

hydrology

(1) The study of water characteristics, especially the movement of water. (2) The study of water, involving aspects of geology, oceanography, and meteorology.

igneous

(1) A type of rock formed from a molten, or partially molten, material. (2) An activity related to the formation and movement of molten rock either in the *subsurface* (plutonic) or on the surface (volcanic).

impact

For an EIS, the positive or negative effect of an action (past, present, or future) on the natural *environment* (land use, air quality, water resources, geological resources, ecological resources, aesthetic and scenic resources) and the human environment (infrastructure, economics, social, and cultural).

implementing alternative

An action or proposition by DOE necessary to implement the *Proposed Action* and to enable the estimation of the range of reasonably foreseeable *impacts* of that action or proposition.

- The implementing rail/intermodal alternatives for Nevada transportation are the five corridors for a new rail spur:
  - Carlin
  - Caliente
  - Caliente-Chalk Mountain
  - Jean
  - Valley Modified
- The five *intermodal transfer station*/heavy-haul route combinations:
  - Caliente intermodal transfer station, Caliente route
  - Caliente intermodal transfer station, Caliente-Chalk Mountain route
  - Caliente intermodal transfer station, Caliente-Las Vegas route
  - Sloan/Jean intermodal transfer station, Sloan/Jean route
  - Apex/Dry Lake intermodal transfer station, Apex/Dry Lake route

DOE decisions on implementing alternatives will be made when they are ripe for decisionmaking, which might occur after a decision to construct and operate the Yucca Mountain Repository.

inadvertent intrusion

The disturbance of a *disposal* facility or its immediate *environment* by a future occupant that could result in a loss of *containment* of the waste or *exposure* of people.

indirect impact

An effect that is related to but removed from a proposed action by an intermediate step or process. Examples include surface-water quality changes resulting from soil erosion at construction sites, and reductions in productivity resulting from changes in soil temperature.

industrial wastewater

Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

inert

Lacking active thermal, chemical, or biological properties. An inert atmosphere is incapable of supporting combustion.

infiltration

The process of water entering the soil at the ground surface and the ensuing movement downward when the water input at the soil surface is adequate. Infiltration becomes *percolation* when water has moved below the depth at which it can return to the atmosphere by evaporation or *evapotranspiration.*

infrastructure

Basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communication systems. These include surface and *subsurface* facilities (for example, service drifts, transporters, electric power supplies, waste handling buildings, administrative facilities).

in situ

In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or underground facility, from those conducted in the laboratory.

institutional control

Monitoring and maintenance of storage facilities to ensure that radiological releases to the *environment* and *radiation* doses to workers and the public remain within Federal limits and DOE Order requirements.

intermodal transfer station

A facility at the juncture of rail and road transportation used to transfer *shipping casks* containing *spent nuclear fuel* and *high-level radioactive waste* from rail to truck and empty casks from truck to rail.

intermodal transfer station candidate area

Area near one or more existing main rail lines that DOE is considering for the location of an *intermodal transfer station.*

intrusive sound

A new sound that, either because of its loudness in relation to the local *ambient* sound level, or because of such characteristics as tone content, impulsive or unexpected nature, or high information content, is annoying or detracts from the usual ambiance of the receptor location. See *noise*.

invert

(1) The low point of something such as a tunnel, *drift*, or drainage channel. (2) An engineered structure or material placed on excavated drift floors (the low points) to serve as structural support for drift transportation or *emplacement* systems. (For precast concrete, the proper name is invert segments, but they are commonly referred to simply as inverts.) Typical inverts (segments) convert rounded excavated floors to flat level surfaces for transportation system use. Emplacement drift inverts may be specially designed to enhance the waste *isolation* and *criticality* prevention capabilities of the proposed repository through choice of invert materials or invert shape. Inverts might also be used to help channel water to improve repository drainage.

involved worker

A worker who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and *emplacement* of waste materials; and *monitoring* of the condition and performance of the *waste packages*. See *noninvolved worker*.

ion

(1) An atom that contains excess *electrons* or is deficient in electrons, causing it to be chemically active. (2) An electron not associated with a *nucleus*.

ionizing radiation

(1) *Alpha particles*, *beta particles*, *gamma rays*, *X-rays*, *neutrons*, high-speed *electrons*, high-speed *protons*, and other particles capable of producing *ions*. (2) Any radiation capable of displacing electrons from an atom or molecule, thereby producing ions.

irradiation

Exposure to *radiation*.

isolation

Inhibiting the transport of *radioactive* material so that the amounts and concentrations of this material entering the *accessible environment* stay within prescribed limits.

isotope

One of two or more atomic *nuclei* with the same number of *protons* (that is, the same *atomic number*) but with a different number of *neutrons* (that is, a different *atomic weight*). For example, uranium-235 and uranium-238 are both isotopes of uranium.

Jackass Flats

A broad asymmetric basin 8 to 10 kilometers (5 to 6 miles) wide and 20 kilometers (12 miles) long that is east of Yucca Mountain and is drained by *Fortymile Wash*.

juvenile failure

Premature failure of a *waste package* because of material imperfections or damage by rockfall during *emplacement*.

land withdrawal area

An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Las Vegas Valley shear zone

A major right-lateral strike-slip zone of faulting.

latent cancer fatalities

Deaths resulting from *cancer* that has become active after a latent period (that is, the period after exposure).

legal-weight truck

A truck with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be within Federal and state regulations.

License Application

An application to the Nuclear Regulatory Commission for a license to construct a repository.

lithology

The study and description of the general, gross physical characteristics of a rock, especially sedimentary *clastics*, including color, grain size, and composition.

lost workday cases

Incidents that result in injuries that cause the loss of work time.

low-income population

One in which 25 percent or more of the persons in the population live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements.

low-level radioactive waste

Radioactive waste that is not classified as *high-level radioactive waste*, *transuranic waste*, or byproduct tailings containing uranium or thorium from processed ore. Usually generated by hospitals, research laboratories, and certain industries.

maintenance

Activities during the repository operation and monitoring phase including maintenance of *subsurface* monitoring and instrumentation systems and utilities (compressed air, water supply, fire water, wastewater system, power supply, and lights), maintenance of the main ventilation fan installations and surface facilities related to underground activities, and site security. Maintenance also preserves the capability to retrieve emplaced *disposal containers*. See *repository phases*.

matrix (geology)

The solid, but porous, portion of rock.

maximally exposed individual

A hypothetical individual whose location and habits result in the highest total radiological or chemical *exposure* (and thus *dose*) from a particular source for all *exposure* routes (for example, inhalation, ingestion, direct exposure). For evaluating the potential postclosure radiological impacts to the public, "maximally exposed individual" is interchangeable with "reasonably maximally exposed individual."

Maximum Contaminant Level

Under the Safe Drinking Water Act, the maximum permissible concentrations of specific constituents in drinking water that is delivered to any user of a public water system that serves 15 or more connections and 25 or more people; the standards established as maximum contaminant levels consider the feasibility and cost of attaining the standard.

maximum reasonably foreseeable accidents

Accidents characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest foreseeable consequences. In general, accidents with conditions that have a chance of occurring more often than 1 in 10 million in a year are considered to be reasonably foreseeable.

metamorphic

Rock in which the original mineralogy, texture, or composition has changed due to the effects of pressure, temperature, or the gain or loss of chemical components.

metric tons of heavy metal (MTHM)

Quantities of *spent nuclear fuel* without the inclusion of other materials such as *cladding* (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume.

millirem

One one-thousandth (0.001) of a *rem*.

minority population

A community in which the percent of the population of a racial or ethnic minority is 20 points higher than the percent found in the population as a whole.

mitigation

Actions and decisions that (1) avoid *impacts* altogether by not taking a certain action or parts of an action, (2) minimize impacts by limiting the degree or magnitude of an action, (3) rectify the impact by repairing, rehabilitating, or restoring the *affected environment*, (4) reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action, or (5) compensate for an impact by replacing or providing substitute resources or *environments*.

mixed-oxide fuel

A mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors.

monitored geologic repository

A system, requiring licensing by the U.S. Nuclear Regulatory Commission, intended or used for the permanent underground *disposal* of *radioactive* waste (including *spent nuclear fuel*). A *geologic repository* includes (1) the geologic repository operations area, and (2) the geologic setting in the *controlled area* that provides *isolation* of the radioactive waste. The repository would be monitored between *emplacement* of the last *waste package* and closure.

monitoring

Activities during the repository operation and monitoring phase including the surveillance and testing of *waste packages* and the repository for *performance confirmation*. See *repository phases*.

National Environmental Policy Act

The Federal statute that is the national charter for protection of the *environment*. The Act is implemented by procedures issued by the Council on Environmental Quality and DOE. The National Environmental Policy Act of 1969 appears at 42 USC 4321 *et seq*.

natural barrier

The physical, mechanical, chemical, and hydrologic characteristics of the geologic *environment* that individually and collectively act to minimize or prevent radionuclide transport. See *barrier*.

natural system

A host rock suitable for repository construction and waste *emplacement* and the surrounding rock formations. It includes *natural barriers* that provide *containment* and *isolation* by limiting radionuclide transport through the geohydrologic *environment* to the *biosphere* and provide conditions that will minimize the potential for *human intrusion* in the future.

naval spent nuclear fuel

Spent nuclear fuel discharged from reactors in surface ships, submarines, and training reactors operated by the U.S. Navy.

near-field

The area of and conditions in the repository including the *drifts* and *waste packages* and the rock immediately surrounding the drifts. The region around the repository where the natural hydrogeologic system would be significantly impacted by the excavation of the repository and the *emplacement* of waste.

neutron

An atomic particle with no charge and an atomic mass of 1; a component of all atoms except hydrogen; frequently released as *radiation*.

nitrogen oxides

Gases formed in great part from atmospheric nitrogen and oxygen when combustion occurs under conditions of high temperature and high pressure; a major air pollutant. Two primary nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), are important airborne *contaminants*. In the presence of sunlight, nitric oxide combines with atmospheric oxygen to produce nitrogen dioxide, which in high concentrations can cause lung damage.

No-Action Alternative

One of the *alternatives* to be assessed in an EIS. The regulations of the Council on Environmental Quality (40 CFR Parts 1500 through 1508) direct Federal agencies to use the process established by the *National Environmental Policy Act* to identify and assess reasonable alternatives, including "no action." For this EIS, under the No-Action Alternative DOE would end *site characterization* activities at Yucca Mountain and continue to accumulate *spent nuclear fuel* and *high-level radioactive waste* at commercial storage sites and DOE facilities.

noble gas

Any of a group of rare gases that include helium, neon, argon, krypton, xenon, and sometimes radon and that exhibit great stability and extremely low reaction rates; also called *inert* gas.

noise

Any sound that is undesirable because it interferes with speech and hearing; if intense enough, it can damage hearing.

noninvolved worker

A worker who would perform managerial, technical, supervisory, or administrative activities but would not be directly involved in construction, excavation, or operations activities. See *involved worker*.

normal fault

A fault in which the relative displacement is along the direction of dip of the fault plane (*dip-slip fault*) where the block above the fault has moved downward in relation to the block below the fault. See *reverse fault*.

nuclear radiation

Radiation that emanates from an unstable atomic *nucleus*.

nuclear reactor

A device in which a nuclear *fission chain reaction* can be initiated, sustained, and controlled to generate heat or to produce useful radiation.

nuclear waste

Unusable by-products of nuclear power generation, nuclear weapons production, and research, including *spent nuclear fuel, high-level radioactive waste*.

Nuclear Waste Policy Act (42 USC 10101 *et seq.*)

The Federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a Federal system for the management and geologic disposal of *commercial spent nuclear fuel* and other *high-level radioactive wastes*, as appropriate. The Act also specified other Federal responsibilities for nuclear waste management, established the Nuclear Waste Fund to cover the cost of geologic *disposal*, authorized interim storage under certain circumstances, and defined interactions between Federal agencies and the states, local governments, and Native American tribes. The Act was substantially amended in 1987 (see *Nuclear Waste Policy Act Amendments of 1987*) and 1992 (see Energy Policy Act of 1992)

Nuclear Waste Policy Act Amendments of 1987 (Public Law 100-203)

Legislation that amended the *Nuclear Waste Policy Act* to limit repository *site characterization* activities to Yucca Mountain, Nevada; establish the Office of Nuclear Waste Negotiator to seek a state or Native American tribe willing to host a repository or monitored retrievable storage facility; create the *Nuclear Waste Technical Review Board*; and increase state and local government participation in the waste management program.

Nuclear Waste Technical Review Board

An independent body established within the executive branch, created by the *Nuclear Waste Policy Amendments Act of 1987* to evaluate the technical and scientific validity of activities undertaken by the U.S. Department of Energy, including *site characterization* activities and activities relating to the packaging or transportation of *high-level radioactive waste* or *spent nuclear fuel*. Members of this Board are appointed by the President from a list prepared by the National Academy of Sciences.

nucleus

The central, positively charged, dense portion of an atom. Also known as atomic nucleus.

nuclide

An atomic *nucleus* specified by its *atomic weight*, *atomic number*, and energy state; a radionuclide is a *radioactive* nuclide.

oblique-slip fault

A *fault* that combines some purely horizontal motion (*strike-slip fault*) with some, along the direction of the dip of the fault plane (*dip-slip fault*).

offsite

Physically not in a repository-related area managed by DOE.

onsite

Physically in an area managed by DOE where access can be limited for any reason. The site boundary encompasses *controlled areas*. The site comprises the various Operations Areas and the areas between and immediately surrounding them.

operational storage

A storage capacity DOE could use to collect material shipped to the repository before (or after) its insertion in *waste packages* and *emplacement* in the repository.

operations

See *repository phases*.

organism

An individual constituted to carry on the activities of life by means of organs separate but mutually dependent; a living being.

overburden

Geologic material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials. As used by the Yucca Mountain Project, this is geologic material overlying the mined *repository horizon*.

overweight, overdimension truck

Semi- and tandem tractor-trailer trucks with gross weights over 80,000 pounds that must obtain permits from state highway authorities to use public highways.

ozone (O_3)

The triatomic form of oxygen; in the *stratosphere*, ozone protects the Earth from the Sun's *ultraviolet radiation*, but in lower levels of the atmosphere it is an air pollutant.

Paleozoic Era

A geologic era extending from the end of the Precambrian to the beginning of the Mesozoic, dating from about 600 to 230 million years ago.

particulate matter

Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. See *PM_{10}*.

pathway

A potential route by which radionuclides might reach the *accessible environment* and pose a threat to humans.

pediment

A planar sloping rock surface forming a ramp to a front of a mountain range in an arid region. It might be covered locally by a thin *alluvium*.

perched water

A *saturated zone* condition that is not continuous with the *water table*, because there is an impervious or semipervious layer underlying the perched zone or a *fault* zone that creates a *barrier* to water movement and perches water. See *permeable*.

percolation

The passage of a liquid through a porous substance. In rock or soil it is the movement of water through the interstices and pores under hydrostatic pressure and the influence of gravity. The downward or lateral flow of water that becomes net *infiltration* in the *unsaturated zone*.

performance assessment

An analysis that predicts the behavior of a system or system component under a given set of conditions. Performance assessments include estimates of the effects of *uncertainties* in data and modeling. See *Total System Performance Assessment*.

performance confirmation

The program of tests, experiments, and analyses conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after *permanent closure* will be met.

permanent closure

Final sealing of *shafts* and *boreholes* of the underground facility.

permeable

Pervious; a permeable rock is a rock, either porous or cracked, that allows water to soak into and pass through it freely.

permeability

In general terms, the capacity of such mediums as rock, sediment, and soil to transmit liquid or gas. Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they interconnect. "Hydraulic conductivity" is equivalent to "permeability" in technical discussions relating to *groundwater*.

person-rem

A unit used to measure the *radiation* exposure to an entire group and to compare the effects of different amounts of radiation on groups of people; it is the product of the average *dose equivalent* (in *rem*) to a given organ or tissue multiplied by the number of persons in the population of interest.

pH

A number indicating the acidity or alkalinity of a solution. A pH of 7 indicates a neutral solution. Lower pH values indicate more acidic solutions while higher pH values indicate alkaline solutions.

photon

A massless particle, the quantum of an electromagnetic field, carrying energy, momentum, and angular momentum.

picocurie

One one-trillionth (1×10^{-12}) of a *curie*.

$PM_{2.5}$

All *particulate matter* in the air with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers (0.0001 inch). A standard for this material as a *criteria pollutant* has been defined but not yet implemented.

PM_{10}

All *particulate matter* in the air with an aerodynamic diameter less than or equal to a nominal 10 micrometers (0.0004 inch). Particles less than this diameter are small enough to be breathable and could be deposited in lungs.

population dose

A summation of the radiation doses received by individuals in an exposed population; equivalent to *collective dose*; expressed in *person-rem*.

portal

Surface entrance to a mine, particularly in a *drift* or tunnel. The North and South Portals are the two primary entrances to the *subsurface* facilities.

preferred route

A public highway route that satisfies the requirements of U.S. Department of Transportation regulations (49 CFR Part 397, Subpart D) to be acceptable for shipments of *Highway Route-Controlled Quantities of Radioactive Material*.

pressurized-water reactor (PWR)

A nuclear power *reactor* that uses water under pressure as a coolant. The water boiled to generate steam is in a separate system.

probabilistic

(1) Based on or subject to *probability*. (2) Involving a variable factor, such as temperature or porosity. At each instance of time, the factor may take on any of the values of a specified set with a certain probability. Data from a probabilistic process is an ordered set of observations, each of which is one item in a probability distribution.

probability

The relative frequency at which an event can occur in a defined period. Statistical probability is about what actually happens in the real world and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile the complete set of, all possible outcomes over time or space. Probability is measured on a scale of 0 (event will *not* occur) to 1 (event *will* occur).

probable maximum flood

The hypothetical flood (peak discharge, volume, and hydrographic shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors, such as sequential storms and snowmelts, that are favorable for maximum flood runoff.

proposed action

The activity proposed to accomplish a Federal agency's purpose and need. An EIS analyzes the environmental *impacts* of the Proposed Action. A proposed action includes the project and its related support activities (preconstruction, construction, and operation, along with postoperational requirements). The Proposed Action in this EIS is the construction, operation and monitoring, and eventual closure of a *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain in Nevada (see *repository project phases*).

proton

An elementary particle that is the positively charged component of ordinary matter and, together with the *neutron*, is a building block of all atomic *nuclei*.

pyroclastic

Of or relating to individual particles or fragments of *clastic* rock material of any size formed by volcanic explosion or ejected from a volcanic vent.

qualitative

With regard to a variable, a parameter, or data, an expression or description of an aspect in terms of non-numeric qualities or attributes. See *quantitative*.

quantitative

A numeric expression of a variable. See *qualitative*.

rad

The unit of measure for the absorbed dose of *radiation*.

radiation

The emitted particles or *photons* from the *nuclei* of *radioactive* atoms. Some elements are naturally radioactive; others are induced to become radioactive by *irradiation* in a *reactor*. Naturally occurring radiation is indistinguishable from induced radiation.

radioactive
: Emitting *radioactivity*.

radioactive decay
: The process in which one *radionuclide* spontaneously transforms into one or more different radionuclides, which are called decay products.

radioactivity
: The property possessed by some elements (for example, uranium) of spontaneously emitting alpha, beta, or *gamma rays* by the *disintegration* of atomic *nuclei*.

radionuclide
: See *nuclide*.

rail route
: Route from point of origin to the repository.

reactor
: See *nuclear reactor*.

reasonably maximally exposed individual
: See *maximally exposed individual*.

recharge
: The movement of water from an *unsaturated zone* to a *saturated zone*.

recordable cases
: Occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Record of Decision
: A document that provides a concise public record of a decision made by a government agency.

region of influence
: The physical area that bounds the environmental, sociologic, economic, or cultural features of interest for the purpose of analysis.

rem
: The unit of a *dose equivalent* from *ionizing radiation* to the human body. It is used to measure the amount of radiation to which a person has been exposed (rem means Roentgen Equivalent in Man).

remediation
: Action taken to permanently remedy a release or threatened release of a hazardous substance to the *environment*, instead of or in addition to removal.

repository
: See *geologic repository*.

repository horizon

The near-horizontal plane in the host rock stratum where DOE proposes to locate the repository emplacement area(s).

repository phases

The development of a monitored geologic repository at Yucca Mountain, if approved, would have three phases, as follows:

- *Construction:* The repository construction phase would begin in 2005 and end in 2010. Activities during this phase would include preparing the site, constructing surface waste handling and support facilities, excavating and equipping a portion of the repository *subsurface* for initial waste *emplacement*, and conducting initial verification testing of components and systems.

- *Operation and monitoring:* Repository operations activities would include waste receipt, repackaging, and emplacement in the repository; continuing subsurface development for waste *emplacement; monitoring; and maintenance.* Waste receipt, repackaging, and emplacement activities, along with continued construction activities, would begin in about 2010 and would take about 24 years. Monitoring would begin with the initial emplacement of waste in the repository and would end at repository closure. In addition, the maintenance of repository facilities would continue until the closure of the repository. See *monitoring, maintenance.*

- *Closure:* The closure of the *subsurface* repository facilities would include the removal and salvage of equipment and materials; filling of the main *drifts*, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and *boreholes*. Surface closure activities would include the construction of monuments to mark the repository location, *decommissioning* and demolition of facilities, and restoration of the site to its approximate condition before the construction of the repository facilities. Closure would begin in 2060 at the earliest or as late as 2310 (that is, from 50 to 300 years after the start of emplacement).

restricted area

An area of the surface repository enclosed by security fences, control gates, lighting, and detection systems established to prevent the spread of radiological contamination. The area would include the facilities and transportation systems required to receive and ship rail and truck waste shipments, prepare *shipping casks* for handling, and load *waste forms* into disposal containers for *emplacement* in the repository. It would also include the facility and systems required to treat and package site-generated *low-level radioactive waste* for offsite disposal. (Other documents related to the Yucca Mountain Repository refer to this as the Radiologically Controlled Area.)

retrieval

The act of removing *radioactive* waste from the underground location at which the waste had been previously emplaced for disposal. Retrieval would be a contingency action, performed only if *monitoring* indicated that the waste needed to be retrieved in order to protect the public health and safety or the environment or to recover resources from *spent nuclear fuel*.

reverse fault

A *fault* in which the relative displacement is along the direction of the dip of the fault plane (*dip-slip fault*), and in which the block above the fault has moved upward in relation to the block below the fault.

riprap

Broken stones or chunks of concrete used as foundation material or in embankments to control water flow or prevent erosion.

risk

The product of the probability that an undesirable event will occur multiplied by the consequences of the undesirable event.

roentgen

The international unit of quantity for X-rays and gamma rays.

safe haven

Designated safe parking locations along transportation routes.

sanitary and industrial solid waste

Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as household waste.

sanitary waste

Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

saturated zone

The area below the *water table* where all spaces (*fractures* and rock pores) are completely filled with water.

scenario

A specific set of actions, activities, and assumptions. Scenarios are identified and analyzed to enable the estimation of the range of environmental impacts associated with the *Proposed Action* and the *No-Action Alternative*. Scenarios evaluated in this EIS include the high, intermediate, and low *thermal load* scenarios, No-Action Alternative Scenario 1 (continued *institutional control*) and Scenario 2 (no effective institutional controls after 100 years). The environmental impacts identified from these scenarios provide environmental information to support Departmental decisions about the *alternatives* and *implementing alternatives*.

seismic

Pertaining to, characteristic of, or produced by *earthquakes* or earth vibrations.

seismicity

A seismic event or activity such as an *earthquake* or earth tremor; *seismic* action.

shaft

An excavation or vertical passage of limited area, compared to its depth, used to lower personnel and material or to ventilate underground facilities.

shielding

Any material that provides *radiation* protection.

shipment

The movement of a properly prepared (loaded, unloaded, or empty) *cask* from one site to another and associated activities to ensure compliance with applicable regulations.

shipping cask

A heavily shielded massive container that meets regulatory requirements for shipping *spent nuclear fuel* or *high-level radioactive waste*. See *cask*.

single-purpose (storage or transportation) cask

A heavily shielded massive container for the dry storage of *spent nuclear fuel*; it is usable for either storage or transportation but not for *emplacement* in a repository. See *cask*.

site boundary

The boundary of the land withdrawal area used for analytical purposes in this EIS. See *land withdrawal area*.

site characterization

Activities from 1986 to 2000 associated with the determination of the suitability of the Yucca Mountain site as a *monitored geologic repository*. DOE constructed the *Exploratory Studies Facility* to support the following activities related to the determination of site suitability, including surface facilities and *subsurface* ramps and *drifts*:

- Gather and evaluate surface and subsurface site data
- Predict the performance of the repository
- Prepare the repository design
- Assess the performance of the system against the required Code of Federal Regulations and program performance criteria

Some of the exploratory surface and subsurface facilities would be enhanced during the repository construction phase (see *repository phases*); others would be removed, demolished, or relocated, as necessary. Data gathering associated with site characterization would end with the beginning of the construction phase.

site-generated waste

Waste or wastewater generated at the *monitored geologic repository* and related transportation facilities.

soil recovery

The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

sound barrier

Natural or artificial structures that block or interfere with the propagation of sound; examples include terrain features and manmade structures (buildings, walls, etc.).

source term

Types and amounts of radionuclides that are the source of a potential release of *radioactivity*.

spalling

(1) Flaking off of corrosion products from the metal *substrate* as it undergoes corrosion. The layer of corroded material thickens. The spalling could be caused by an expansive action of the corrosion products because they occupy a greater volume than the uncorroded metal substrate. (2) Flaking, chipping, or cracking at the opening of a *borehole*, *shaft*, or other rock excavation.

Special-Performance-Assessment-Required (SPAR) wastes

Low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

spent nuclear fuel

Fuel that has been withdrawn from a nuclear *reactor* following *irradiation*, the component elements of which have not been separated by reprocessing. For this project, this refers to (1) intact, nondefective *fuel assemblies*, (2) failed fuel assemblies in canisters, (3) fuel assemblies in canisters, (4) consolidated fuel rods in canisters, (5) nonfuel assembly hardware inserted in *pressurized-water reactor* fuel assemblies, (6) fuel channels attached to *boiling-water reactor* fuel assemblies, and (7) nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in *canisters*.

spoils areas

Areas outside the rail corridor for the deposition of excavated materials from rail line development.

stakeholder

A person or organization with an interest in or affected by DOE actions (representatives from Federal, state, tribal, or local agencies; members of Congress or state legislatures; unions, educational groups, environmental groups, industrial groups, etc.; and members of the general public).

storage

The collection and containment of waste or *spent nuclear fuel* in a way that does not constitute *disposal* of the waste or *spent nuclear fuel* for the purposes of awaiting treatment or disposal capacity.

storage cask

See *cask*.

storage container

See *cask*.

stratigraphy

The branch of geology that deals with the definition and interpretation of rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification. See *stratum*.

stratosphere

The atmospheric shell above the troposphere and below the mesosphere. It extends from 10 to 20 kilometers (6 to 12 miles) to about 53 kilometers (33 miles) above the surface.

stratum

A sheetlike mass of sedimentary rock or earth of one kind lying between beds of other kinds.

stream tube

A modeling method used to represent the *groundwater* flow path from the *water table* to the *biosphere*. There are six stream tubes used for *saturated zone* modeling with one tube associated with and having the cross-sectional shape of one of six regions designated at the water table. Each stream tube takes in *groundwater* flux and radionuclide mass flux data at the water table representing flux from the repository that would pass through the *unsaturated zone*.

strike-slip fault

A fault with purely horizontal relative displacement.

subcritical

Having an effective multiplication constant less than 1, so that a self-supporting *chain reaction* cannot be maintained in a *nuclear reactor*.

substrate

Basic surface on which a material adheres.

subsurface

A zone below the surface of the Earth, the *geologic* features of which are principally layers of rock that have been tilted or faulted and are interpreted on the basis of drill hole records and geophysical (*seismic* or rock vibration) evidence. In general, it is all rock and solid materials lying beneath the Earth's surface.

sulfur dioxide

A toxic gas produced from the burning of fossil fuels. It is the main pollutant involved in the formation of acid rain. Coal-burning electric utilities are the major source of sulfur dioxide in the United States. See *criteria pollutants, ambient air quality standards*.

sulfur oxides

Pungent, colorless gases formed primarily by the combustion of fossil fuels; considered major air pollutants; sulfur oxides can damage the human respiratory tract and vegetation. See *criteria pollutants, ambient air quality standards*.

supernate

A concentrated form of *radioactive* waste that floats to the top of an undisturbed container of liquid *high-level radioactive waste*.

thermal load

The application of heat to a system, usually measured in terms of watts per unit area. The thermal load for a repository is the watts per acre produced by the *radioactive* waste in the active *disposal* area. The spatial density at which waste packages are emplaced within the repository as characterized by the areal power density and the *areal mass loading*.

threatened species
A species that is likely to become an *endangered species* within the foreseeable future throughout all or a significant part of its range.

thrust fault
A *reverse fault* in which the angle of the fault plane is less than 45 degrees.

Total System Performance Assessment
A risk assessment that quantitatively estimates how the proposed Yucca Mountain Repository system would perform under the influence of specific features, events, and processes, incorporating *uncertainty* in the models and data. See *performance assessment*.

toxic air pollutants
Hazardous pollutants not listed as either *criteria pollutants* or *hazardous pollutants*.

transpiration
The process by which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.

transuranic waste
Waste materials (excluding high-level radioactive waste and certain other waste types) contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and that occur in concentrations greater than 100 nanocuries per gram. Transuranic waste results primarily from treating and fabricating plutonium as well as research activities at DOE defense installations.

tuff
Igneous rock formed from compacted volcanic fragments from *pyroclastic* (explosively ejected) flows with particles generally smaller than 4 millimeters (about 0.16 inch) in diameter. The most abundant type of rock at the Yucca Mountain site.

ultraviolet radiation
Electromagnetic radiation with wavelengths from 4 to 400 nanometers. This range begins at the short wavelength limit of visible light and overlaps the wavelengths of long *x-rays* (some scientists place the lower limit at higher values, up to 40 nanometers). Also known as ultraviolet light.

uncanistered spent nuclear fuel
Fuel placed directly into storage containers or shipping casks without first being placed in a canister.

uncertainty
A measure of how much a calculated or estimated value that is used as a reasonable guess or prediction might vary from the unknown true value.

unsaturated zone
The area between the surface and the *water table* where only some of the spaces (*fractures* and rock pores) are filled with water. See *saturation zone*.

vadose zone

See *unsaturated zone*.

Viability Assessment

An assessment of the prospects for geologic disposal at the Yucca Mountain site, based on repository and *waste package* design, a *Total System Performance Assessment*, a *License Application* plan, and repository cost and schedule estimates. DOE issued the *Viability Assessment of a Repository at Yucca Mountain* in December 1998.

vicinity (in relation to the Yucca Mountain Repository)

A general term used in nonspecific discussions in this EIS about the area around the Yucca Mountain site.

vitrification

A waste treatment process that uses glass (for example, *borosilicate glass*) to encapsulate or immobilize *radioactive* wastes.

waste form

A generic term that refers to *radioactive* waste materials and any encapsulating or stabilizing matrix.

waste package

The *waste form* and any containers (that is, *disposal container* barriers and other canisters), spacing structure or baskets, *shielding* integral to the container, packing inside the container, and other absorbent materials immediately surrounding an individual waste container placed internally to the container or attached to the outer surface of the disposal container. The waste package begins its existence when the outer lid welds are complete and accepted.

water table

The upper limit of the *saturated zone* (the portion of the ground wholly saturated with water).

welded tuff

A *tuff* deposited under conditions where the particles making up the rock were heated sufficiently to cohere. In contrast to nonwelded tuff, welded tuff is denser, less porous, and more likely to be fractured (which increases *permeability*).

wet storage

Storage of *radioactive* material that uses water for cooling or *shielding*.

X-rays

Penetrating electromagnetic *radiation* having a wavelength much shorter than that of visible light. X-rays are identical to *gamma rays* but originate outside the *nucleus*, either when the inner orbital *electrons* of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons.

Yucca Mountain Repository EIS

See *environmental impact statement (EIS)*.

Yucca Mountain site (the site):

The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

zeolite

Any of a group of hydrated silicates of aluminum with alkali metals, commonly occurring as secondary minerals in cavities in basic volcanic rocks.

zirconium alloy

An alloy material containing the element zirconium that might have any of several compositions. It is used as a *cladding* material.

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CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter[a]	1	Parts/million	Parts/million[a]	1	Milligrams/liter
Micrograms/liter[a]	1	Parts/billion	Parts/billion[a]	1	Micrograms/liter
Micrograms/cu. meter[a]	1	Parts/trillion	Parts/trillion[a]	1	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. These widely used conversions are only valid under specific temperature and pressure conditions.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	
exa-	E	1,000,000,000,000,000,000	$= 10^{18}$
peta-	P	1,000,000,000,000,000	$= 10^{15}$
tera-	T	1,000,000,000,000	$= 10^{12}$
giga-	G	1,000,000,000	$= 10^{9}$
mega-	M	1,000,000	$= 10^{6}$
kilo-	k	1,000	$= 10^{3}$
deca-	D	10	$= 10^{1}$
deci-	d	0.1	$= 10^{-1}$
centi-	c	0.01	$= 10^{-2}$
milli-	m	0.001	$= 10^{-3}$
micro-	μ	0.000 001	$= 10^{-6}$
nano-	n	0.000 000 001	$= 10^{-9}$
pico-	p	0.000 000 000 001	$= 10^{-12}$